POWER

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The Engineman and the Engineer

THE automobile driver who has to stop to figure out just what to do in every circumstance is a dangerous man upon the road.

If he had to make a conscious calculation of the relative speed of his car and a car that he wanted to pass, and the distance and speed of an approaching car, and his possible rate of acceleration, and what he must do to bring this about, he would be under arrest all the time for obstructing traffic.

If the golfer or the billiard player paused in his stroke to analyze all the elements of a successful shot and consciously tried to apply them, he would be a dub.

If a child had to comprehend all the complex problems of momentum and inertia, of balance and equilibrium attendant upon the process of walking before he could take a step, we should be going upon all fours.

The things that one does habitually and well he does subconsciously, instinctively, without conscious mental effort.

Such subconscious action comes from habit, practice, the repetitive performance of certain acts. It is the supreme qualification for the operator, for the man upon whose controlling action the safe and continuous action of an aggregation of mechanism depends.

Thousands are doing thousands of things of the principles and mechanics of which they have not the slightest conception. Dry goods clerks who do not know the carburetor from the oil pump drive automobiles cleverly; not one baseball pitcher in hundreds knows anything of the theory of ballistics, and few even among accomplished musicians could pass a satisfactory examination on the science of musical sounds.

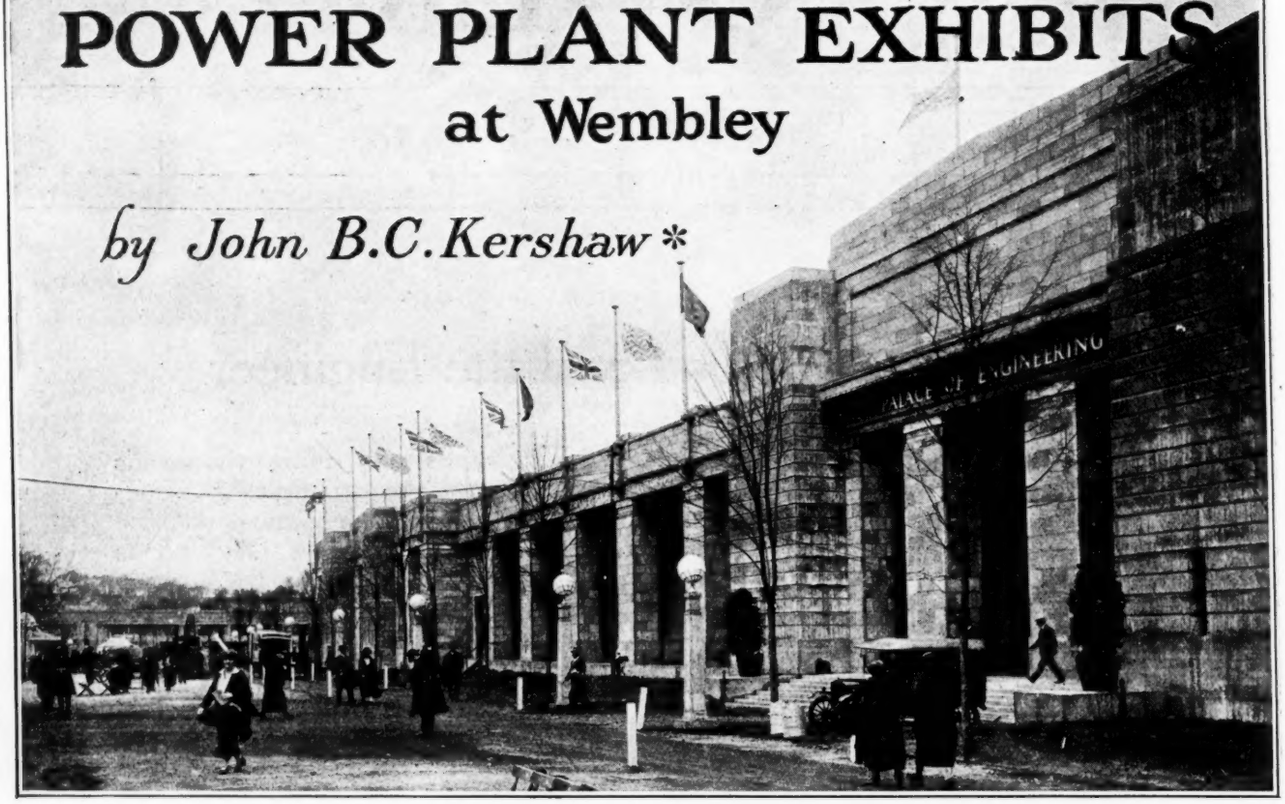
But when we begin to deal with the non-repetitive processes, when we begin to call the conscious mental process into action and to apply fundamental principles and natural laws to new combinations and operations, when we begin to work with the head as well as with the hands, we begin to differentiate between the engineer and the engineman.

And the man who, to an intimate acquaintance with power-plant apparatus born of long manipulation and association, has added such knowledge of its laws and limitations as will enable him to select the best for a given purpose, to operate it at its greatest efficiency, to foresee and prevent trouble, but quickly to diagnose it when it occurs, and reduce rational possibilities to practice, is a real engineer, however he may have come by his knowledge.

F. R. Low

POWER PLANT EXHIBITS at Wembley

*by John B.C. Kershaw**



THE Palace of Engineering, which houses the engineering exhibits at the British Empire Exhibition, is probably the largest concrete building in the world, for it is 1,000 ft. long by 750 ft. broad at its widest points, with a floor space of over half a million square feet. An idea of the simplicity and dignity of the design may be gained from the view used here as a headpiece; it carries no useless ornamentation and, like its contents, possesses only the beauty of sheer efficiency and adaptation to its main purpose. The interior of the building is divided into blocks or bays by 15 main avenues and 38 cross avenues. Five full-gage railway lines traverse the interior of the building from end to end and are connected outside with the main trunk lines of the British Railway System. With the aid of these switch tracks and the overhead traveling cranes lifting up to 25 tons in weight, which run the whole length of the main avenues, the exhibits have been got into place with the greatest ease and with remarkable speed.

The heavier exhibits have been accommodated as far as possible in the larger bays, each 75 ft. wide, which occupy the center and south side of the building, and here we find those illustrating shipbuilding, marine, mechanical and general engineering, while the exhibits of electrical and allied branches of engineering fill the section to the north, and the railway, motor and water transport exhibits are housed in the bays on the east side of the building. A modern power house, which supplies the whole Exhibition with electricity for lighting and heating purposes, is housed in the northeast corner; and as it is in continuous operation, it forms not the least attractive feature of the show to many of the visitors.

One's first impression on entering the building is the impossibility of gaining knowledge of all its contents, for over 600 firms are exhibiting their manufactures within its walls. Some of them, such as the Metropolitan Vickers Electrical Co. and William Beardmore & Co., seem to cover every branch of engineering activity, for since the war they have launched out in many new directions and have absorbed or obtained an interest in many subsidiary firms engaged in allied branches of manufacturing industry. The exhibits vary in size from full-size modern locomotives, Pullman cars and 16-in. guns, to valves for wireless sets and optical instruments.

The coal-handling machinery in the exhibition power plant was designed by the Mitchell Conveyor & Transporter Co., of London, which also has an exhibit of its ash- and coal-handling equipment. Fig. 2 shows the Mitchell side-discharging car tippler.

The ash-handling plant in the power house was designed by Babcock & Urlex, and is based upon the removal of the wet ashes from a water tank by a revolving paddle which discharges them onto a traveling plate conveyor.

The four boilers in the power plant, while not the largest of their types, represent leading features of modern English design. Two of them are B. & W. horizontal water tubes, of a design well known in the United States. The other two were built by John Thompson & Co., of Wolverhampton, and possess distinctive features. As shown in Fig. 1, each boiler has two sets of upper and two lower drums, each set being connected by straight tubes. The line to the superheater leads out from a cross-connection of the top drums.

These boilers are operated at 220 lb. gage with a

*British correspondent.

steam temperature of 600 deg. F., normal output 20,000 lb. per hour, and are fitted with John Thompson induced-draft chain-grate stokers, 13 ft. 9 in. long by 5 ft. wide. The superheaters are of the expanded-tube type, each having 956 sq.ft. of surface.

Among the exhibits, Yarrow & Co. show a model of a Yarrow stationary boiler, Fig. 3. This model stands 14 ft. high and is fitted with superheaters and an air preheater. Considerable historical interest is aroused by the exhibit of the original Yarrow boiler built in 1887.

The Nesdrum boiler, shown by Richardson, Wesgarth & Co., Hartlepool, while quite different from the typical British boiler, is quite similar to the Bigelow-Hornsby boiler in this country. The back rows of tubes act as an economizer. The boiler is constructed for pressures up to 350 lb. and with a capacity of 32,000 lb. per hour.

E. Green & Co., Wakefield, exhibit a new type of economizer built for modern high pressure. The "Ringstay" economizer is shown in Fig. 4 and is characterized by the staying of every third or fourth joint in each section, together with a reduction in diameter of the interval cap. A circular rather than a rectangular top header is used. The ringstay joint consists of a split cast-iron ring that rests on a shoulder on the tube and is bolted to the header.

The same firm also exhibits a new form of rectangular air preheater, designed to meet the demand that now exists for an air heater of light construction and long life. The Green air heater consists of a number of elements grouped together. Each element comprises four rectangular tubes cast in one piece with a flange at each end. The flange faces of the elements are machine ground, and the intermediate pairs of flanges are held together by bolts. The boundary flanges on the air inlet and outlet sides are bolted to suitable airtight sectional framework, with a converging mouthpiece opposite each tube, in order to prevent undue eddying of the air. Each element weighs approximately 80 lb. and is therefore much heavier than a heater of the same surface constructed of thin sheet-iron plates. A heater of sufficient capacity to supply the requisite quantity of air at a high temperature to the grate of a water-tube boiler need not take up more than three or four feet headroom, casing included, as the whole of the top of the boiler, being otherwise waste space, can be covered with these elements.

The Howden-Ljungstrom air preheater, invented by the Swedish engineers, Aktiebolaget Ljungstroms Angturbin, Stockholm, is shown by James Howden & Co., of Glasgow. The construction of this preheater is familiar to American engineers, being described in *Power*, Aug. 8, 1922.

The same firm, James Howden & Co., exhibits its system of hot forced draft which it claims has been applied to upward of 24,000,000 hp. at sea and is now being adopted for land installations. While certain improvements in detail have been made, the original features remain as designed by the inventor, the late James Howden.

The Sirocco system of mechanical boiler draft is illustrated in the exhibits of Messrs. Davidson & Co., of Belfast, and also by an installation of these fans in the boiler house of the Exhibition.

The builders have also devoted attention to the design and manufacture of fans for removing flue dust from the waste gases of boiler plants. It is important to note that this collection and removal of fine dust and ash from these gases will become of increasing importance as the use of pulverized fuel becomes more general and widespread. Fig. 5 shows the type of collector designed for this work.

The Weir multijet-nozzle heater shown by G. J. Weir, is a new apparatus for heating feed water by means of the exhaust steam, without the noise and vibration

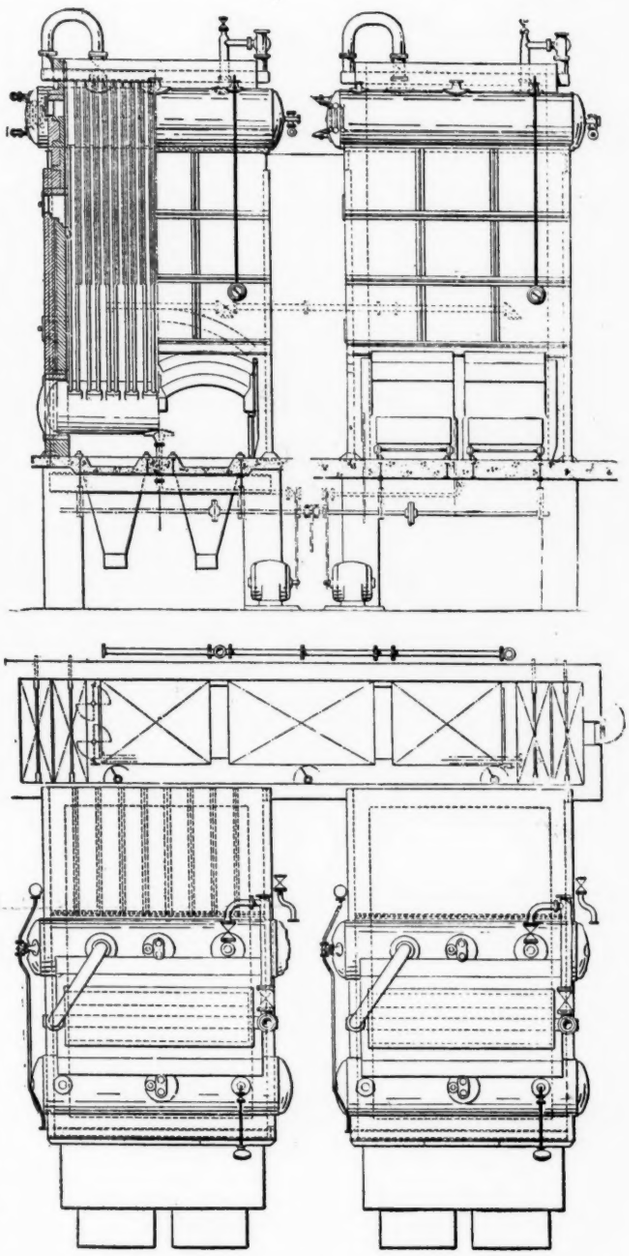


Fig. 1—Thompson four-drum vertical boiler

which usually accompany the direct contact of the steam with the water to be heated. The designers of this nozzle have been able to produce an apparatus that is silent in operation up to 180 deg. F., and even when employing steam at 200 deg. F. the pulsations are of a subdued character.

Feed-water deaërators are exhibited by two firms, Allen Sons & Co., Bedford, and Richardson, Westgarth & Co., of Hartlepool.

Water can be completely deaërated by creating vio-

lent ebullition and foaming, and in the Allen "Contraflo" deaërator this final effect is obtained by flashing the water, whereby it is shattered into minute particles, which allow for the complete liberation of the contained gases. This flashing can be accomplished either by heating the water under vacuum and flashing it on a surface of high temperature, or by first heating it in a separate vessel and then introducing it into a chamber under vacuum. The former arrangement, which is illustrated in Fig. 6, permits the apparatus to be constructed in the form of a self-contained unit. The lower part of the deaërator contains a bank of steam-heated tubes, over which the water falls. Preliminary deaëration takes place in the upper part of the deaërator, where the incoming water is heated to the boiling point by the vapor rising from the hot tubular surface below. This hot surface acts like a low-pressure flash boiler,

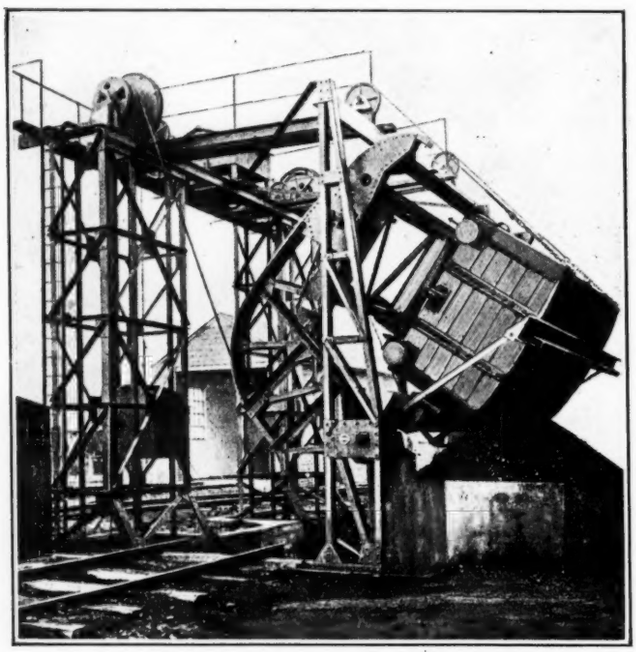


Fig. 2—Mitchell car dumper

and when the falling water comes in contact with it, it is repeatedly flashed as it falls from one tube to another on its way to the outlet, and the contained air is completely liberated. The air rises and is withdrawn at the top by a small steam-operated ejector, which maintains a vacuum in the deaërator corresponding to the temperature of the heated water. The float contained in the base of the deaërator controls the inlet of the water, in accordance with the requirements of the boiler-feed pump.

The deaërator built by Richardson, Westgarth & Co., is known under the trade name of the "Eliminair" deaërator. It is automatic in operation and will reduce the oxygen contents of the feed to an amount that is practically immeasurable, by ordinary chemical methods.

Several exhibits deal with feed-water purification from scale-forming constituents as the latter method is known in the United Kingdom. The Kennicott water softener is installed in the power house of the Exhibition by John Thompson & Co., who hold the licence for its use in Great Britain. The Lassen Hjort water softener is shown by the United Water Softeners, Ltd., who also exhibit the Zeolitic methods. Crosfield & Sons, of Wartington, soap makers, have developed a new method of preparing the base which increases the porosity of the artificial zeolite and therefore reduces the time required for the chemical reaction between the base of the softening agent and the impurities of the water. This new artificial zeolite is a double silicate of sodium and

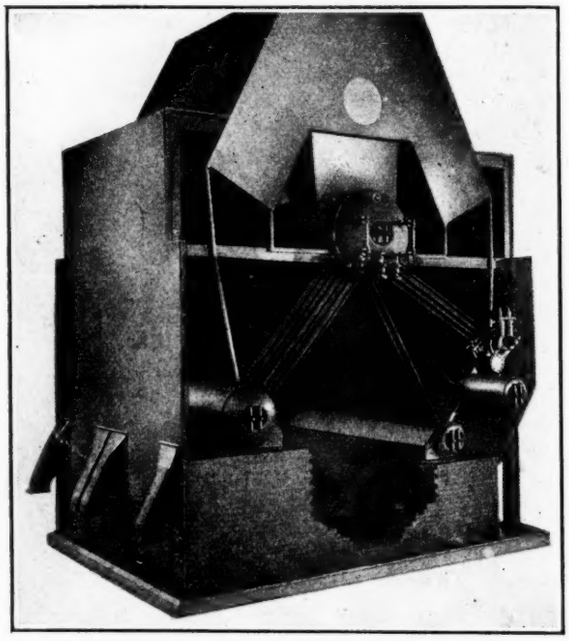


Fig. 3—Yarrow water-tube boiler

aluminum, obtained by a patented process in the form of a gel, and this is now being placed on the market under the trade name of "Doucil." The claims made for this zeolite are that owing to its greater porosity, a much greater proportion of its active substance shares in the reaction and that therefore the quantity of water that can be softened per unit of the material used is largely increased; or what amounts to the same thing, the time required for softening is considerably reduced.

With regard to special types of furnace and grate for

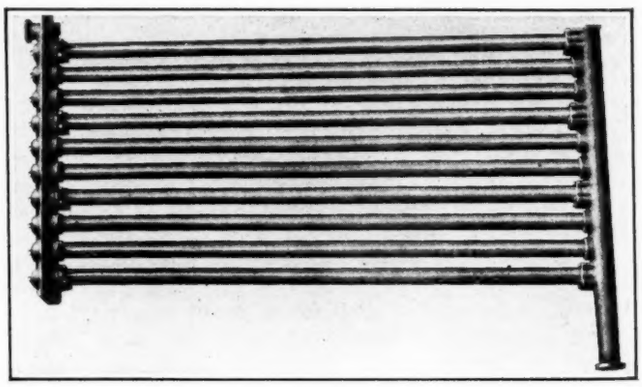


Fig. 4—Ringstay economizer

steam boilers, the Exhibition has not much that is noteworthy to offer to its visitors. The Turbine Furnace Co., of London, shows it latest design of turbine furnace which, it is claimed, greatly increases the efficiency of the Lancashire or tubular type of boiler. As the name implies, the furnace is designed on the lines of an impulse turbine, the air trough under the

firebars representing the nozzle and the firebars themselves the blades of the turbine. The air troughs below the firebars are constructed with a diminishing

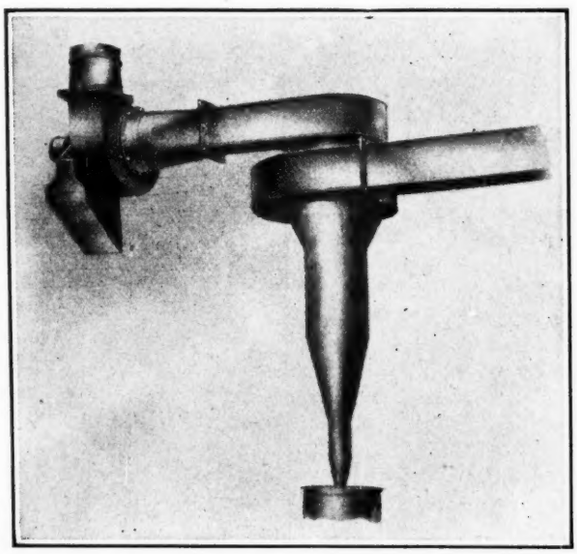


Fig. 5—Sirocco dust collector

section, thus securing an even flow of air for combustion.

James Hodgkinson, Ltd., of Manchester, have an exhibit showing the latest form of their coking-type of

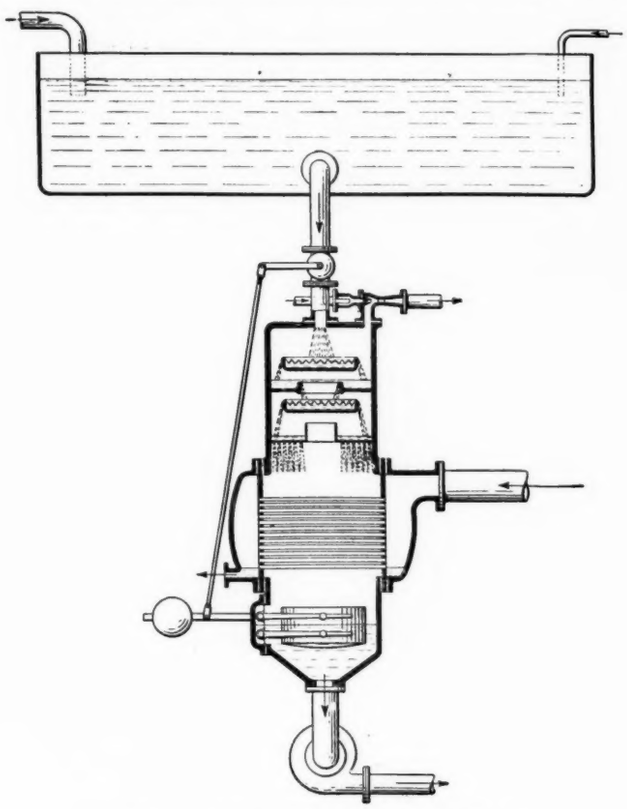


Fig. 6—Allen "Contraflow" deaërator

mechanical stoker. Its chief feature is the inclosed driving gear. This insures efficient lubrication and freedom from dust. With the use of chilled castings for the firebar jaws and for the cams of the driving mechanism, the cost of upkeep, which is sometimes a heavy item with mechanical stokers, is reduced to a minimum.

Pulverized fuel equipment is represented by the Atritor pulverizer marketed by Alfred Herbert & Co., Coventry. Fig. 7 shows an internal view of the apparatus. It will be seen that the body of the machine is a casing which protects all the working parts. The casing contains a horizontal shaft which runs upon inclosed ball bearings, having upon it a steel disk carrying beaters or pegs upon either face. These beaters are arranged to co-operate with similar beaters carried by detachable disk-shaped cheeks on the main frame of the machine. The coal enters at the center and passes outward to the circumference through the beaters, then around the edge of the disk and inward toward the center across the second face of the disk and through the second set of beaters. The first set of beaters is

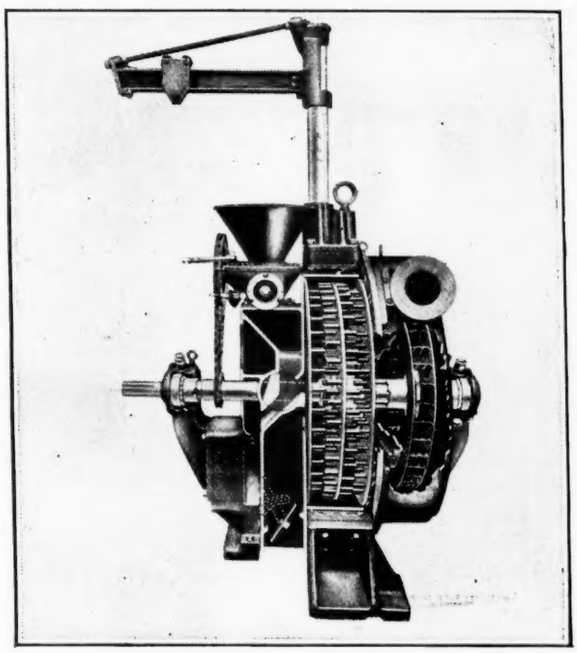


Fig. 7—Novel coal pulverizer

termed the "first effect" and the second set the "second effect."

Refractory bricks and linings for furnaces are exhibited by the Castlecary Fireclay Co., of Glasgow and Airdrie, Scotland. The thermal stability tests of the Castlecary firebrick, correspond to 36 Seger Cone = 1,790 deg. C., or 3,254 deg. F.

A very complete exhibit of coal and water weighing apparatus is shown by the Lea Recorder Co., Manchester. The aparatus includes a feed-water measuring device of the indicating, recording and integrating type, a tilemeter which indicates the rate of flow over a weir at any instant, a coal sampler and two designs of coal meters.

The Lassen water meter, Fig. 8, is of the automatic tipper design. A double-chambered bucket oscillates on a shaft within the water tank. The water flows into a compartment, and when this is full the disturbance of equilibrium causes the tipper to overbalance and the water is discharged into the tank; at the same time the second compartment is brought under the control valve and is filled in turn. An automatic gear is

employed by which the tipper is locked until the required height is reached in the compartment.

Among the boiler safety devices is a Hilo water alarm manufactured by R. Trist & Co., shown in Fig. 9. Two open buckets are connected to a spindle, and at the normal working water level the lower one alone is submerged and its upward thrust holds the whistle closed. At high level both buckets are submerged and as the lower bucket is heavier than the top one, it moves the valve rod opening the whistle. At low levels both buckets are out of water and the lower bucket moves the spindle down, opening the whistle.

Still another safety device shown by the same firm is an oil cutoff for oil-field boilers which, when the boiler-water level becomes dangerously low, closes the oil line to the burner.

George Kent, London, exhibits a line of venturi meters. The meter illustrated in Fig. 10 integrates

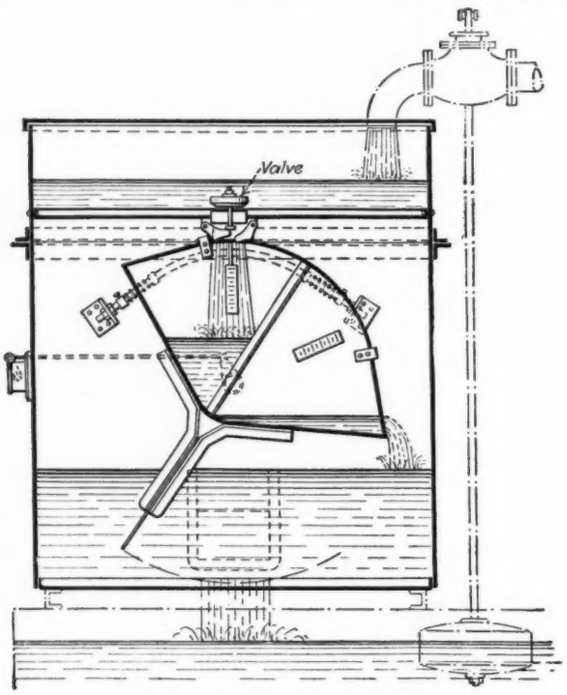


Fig. 8—Lassen water meter

the flow continuously by the planimeter method and so avoids errors due to violent flow fluctuations. The counter mechanism is geared to the spindle of a wheel periphery and rests against a vertical disk rotated at a constant speed by clockwork. The square root progression is converted into equal-spaced movement by the combination of a volume-adjusting chamber and a link motion which transmits the vertical float motion to a spindle.

A most unusual boiler damper is among the exhibits of James Gordon & Co. This, illustrated in Fig. 11, is constructed over the Venetian blind principle. It consists of a cast-iron frame set in the flues and fitted with a number of cast-iron shutters. The position of these shutters is controlled by a vertical control rod which is shifted by the regulating device. The regulator is essentially an iron case containing a diaphragm, on one side of which water is acting under pressure from the steam main; on the other side pressure is exerted by a column of mercury of a height corresponding to the desired pressure. This firm also shows a draft gage which affords direct reading of the draft by means of a point moving over a large dial scale. The instrument shown includes a draft pressure gage for use when forced draft is employed. In this way the drafts in the air duct and above the fire are obtained simultaneously.

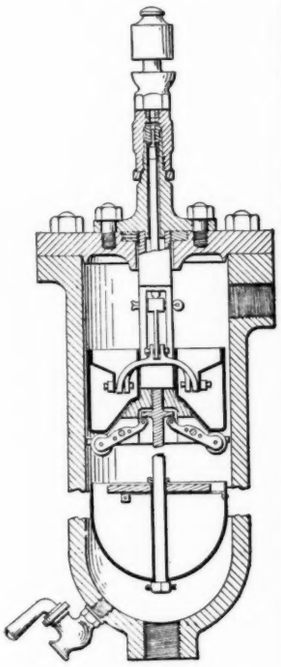


Fig. 9—Hilo water alarm

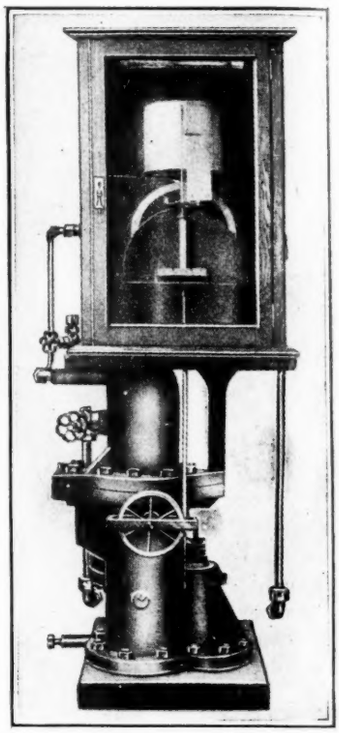


Fig. 10—Kent venturi flow meter

A most unusual device is exhibited by Filtretors, Ltd., London. The apparatus is a finned chamber in which is placed linseed and common soda. The upper part of the chamber is connected to the steam space of the boiler, while the lower line enters the boiler below the water line. Steam entering the device condenses and extracts the glue or mucilage in the linseed. The glue passes continuously to the boiler, where it mixes with the boiler water. When the solids in the water are precipitated, the particles are acted upon by the

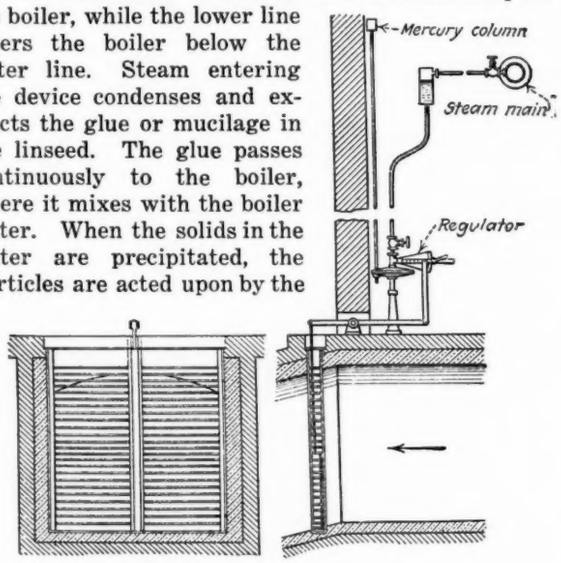


Fig. 11—New design of draft damper

glue and prevented from adhering to each other or to the surface of the boiler. Apparently, the method is successful, for in one case a marine boiler was in service for over a year, using sea water without trouble.

(Continued next week)

High Pressures and High Temperatures in Central Stations

By W. S. MONROE
President, Sargent & Lundy, Chicago, Illinois

IN A paper before the World Power Conference the author discusses reheating and regenerative cycles, describes the arrangement employed at the Crawford Avenue Station and shows why initial cost with 550 or 600 pounds need be but little more than with 300 pounds pressure.

WHEN it comes to operating turbines on steam pressures above 350 lb., difficulties arise that are not so apparent at lower pressures. As steam expands through a turbine, the temperature rapidly falls, owing to expansion and the conversion of heat into work, and a point is reached in the turbine where the steam loses all its superheat, and particles of moisture begin to appear in the steam. This moisture or condensation increases as the steam passes through the lower stages, and the admixture of water with gaseous steam increases the surface friction, and with high velocities erodes the leading edges of the blades, all of which contribute to reduce the blade efficiency of the lower stages. This is one of the main reasons that it is desirable to increase the temperature with increase in pressure.

Assuming a turbine working on 300 lb. gage and 650 deg. F., the steam will lose its superheat when expanded down to about 25 lb. gage. At 400 lb. initial pressure and 675 deg. F. it would lose it at about 35 lb. and the lower stages in the turbines would contain an increased amount of moisture. At 550 lb. and 700 deg. F. initially, moisture would begin to appear at about 55 lb. With an initial pressure of 550 lb. it would be desirable to have a steam temperature of about 1,000 deg. F. in order that there should not be too much condensation in the lower stages of the turbine. But steam temperatures are limited by the reduction in the strength of metals as the temperature increases. This condition leads to the desirability, when operating at the higher pressure, of "reheating" the steam after it has passed through part of the turbine, and a great deal of consideration has been given of late by turbine designers and central-station engineers to the so-called "reheating cycle." This is merely a modification of the Rankine cycle, and it contemplates taking the steam out of the turbine after it has expanded through the high-pressure portion, passing it through some kind of a reheater in which the temperature is increased and returning it again to the turbine.

Some idea of the gain that can be made in cycle efficiency by the reheat cycle combined with an increase in pressure and superheat is shown by the temperature-entropy diagrams in Fig. 1. In this, the area *B* represents a turbine working on 275 lb. gage, 565 deg F. initial steam temperature and 1 in. of mercury absolute back pressure, which was good central-station practice before the war. Area *C* shows the heat available for conversion into work by a turbine operating on 550 lb. gage pressure 725 deg. F. initial temperature, reheating at 105 lb. to 725 deg. F. and exhausting into a vacuum of ¾ in. of mercury absolute pressure. The thermal efficiency of the former cycle is 34.4 per cent and of the latter is 39.8 per cent, which indicates an improvement in fuel efficiency of 15.7 per cent. These figures refer, of course, to the theoretical cycle and to the turbine efficiency only, without any allowance for the boiler room.

It should be added that the efficiency of the 550-lb. cycle without reheat is 38.7 per cent, which shows a theoretical heat saving of only 2.8 per cent due to the reheating, but the actual gain will be more than that, because of the reduction in moisture in the steam through the lower stages of the turbine and the consequent improvement in the efficiency of the turbine blading. Just how much this will amount to will not be definitely known until we have more actual data on plants operating on a reheating cycle, but it is estimated by various turbine designers that it will amount to from 2¼ to 3½ per cent, so that the heat gain due to reheating to 725 deg. F. should be from 5 to 6 per cent. These figures allow for a pressure drop of 10 to 12 lb. through the reheater and piping, but if this pressure drop should be excessive, the value of the reheating will fall off rapidly.

As to the temperature that is practicable for either the initial or the reheated steam, it is limited by the falling off in the strength of metals with increase of temperature. As temperatures were increased in the earlier turbine installations, it was found that cast iron could not be used for valve bodies, fittings or turbine parts if exposed to temperatures over about 500 deg. F. Castings were found to warp and deteriorate in strength in a comparatively short time when used for the higher temperatures. With steel, both cast and wrought, the limits are higher.

Many tests have been made in the last few years to determine the variations in strength of metals with increase in temperature, and these all indicated a quite distinct falling off in both elastic limit and ultimate strength at some point between 700 and 800 deg. F. The curves of Figs. 2 and 3 show the results of such tests on some of the more important metals used in valves, fittings and turbine parts. It must be added also that there is little information as to the effect of time on the strength of these metals at the higher temperatures. It is quite possible that over a period of months or years the strength of metals subjected to temperatures around 700 deg. F. may show a falling off that is not apparent when they are tested after only a brief exposure. Most turbine designers and central-station engineers are agreed that, in the present state of the art, the practical limit of temperature for continuous operation is about 750 deg. F. and that 800 deg. F. may be looked upon as the extreme limit for short periods.

It is true that temperatures higher than these are already being used in the oil refineries, but in comparatively small volumes, and there are no moving elements such as in a turbine.

There is another modification of the Rankine steam cycle that must always be taken into account in any consideration of high-pressure steam plants, and that is the so-called "regenerative cycle." This consists of a scheme for heating the feed water by steam extracted from the turbine at various points. Very early in the development of the turbine surface condensers became standard practice because in them the steam is condensed into pure distilled water and can be returned to the boilers uncontaminated by oil or by the circulating water. The water is condensed at the temperature of the vacuum about 70 deg. F. for 1 in. absolute vacuum, and in the earlier plants it was the general practice to heat the feed water by means of exhaust steam from steam-driven auxiliaries, and later economizers became general in the larger stations to further heat the water by means of the flue gases before it went to the boilers.

The value of regenerative feed heating for compound and triple-expansion engines was pointed out by James Weir, of Glasgow, Scotland, before 1890, but its adaptability to the steam turbine was emphasized by S. Z. de Ferranti, of Manchester, England, some years later, and the cycle is usually associated with his name. The efficiency of the usual steam-driven auxiliaries is low,

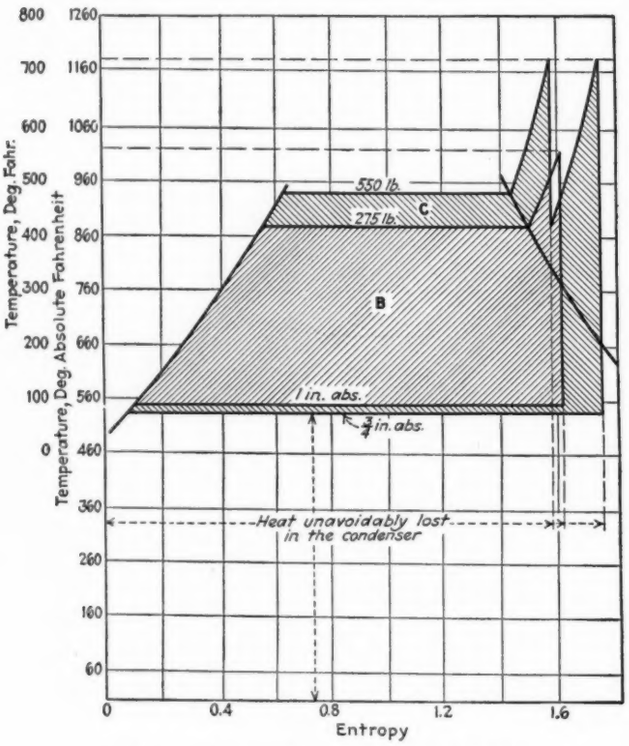


Fig. 1—Comparison of Steam Cycles
"B" 275 lb. gage, 565 deg., 1 in. abs. "C" 550 lb. gage, 725 deg., reheating at 105 lb. gage.

and Mr. de Ferranti pointed out that it is far more efficient to heat the feed water by steam extracted from the turbine after it has done work through the higher stages and use motor-driven auxiliaries. To get the best results, the heating must be done by a series of feed-water heaters; that is, the condensate is first heated by a heater taking steam from one of the lower stages of the turbine at a pressure slightly above the absolute pressure in the condenser. The temperature of this steam, however, will be about 125 or 150 deg. F. according to the stage at which the connection is made, so that by such a heater the water can be heated to something under that temperature. Then, by putting it through another heater taking steam from a higher stage of the turbine, the feed temperature can be increased accordingly. This process can be continued through a series of heaters until the feed water is heated up to any temperature less than that of saturated steam at the initial pressure.

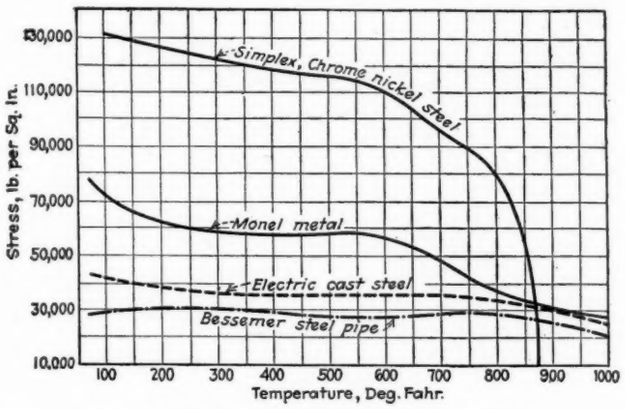


Fig. 2—Elastic Limit of Metals at High Temperature

To carry the regenerative cycle to its theoretical limit would require a large number of heaters, one for each stage or row of blades in the turbine, but this, of course, is impossible in practice, and as a rule not more than three or, at the most, four heaters are used. There is a distinct gain in the plant efficiency by this method of feed-water heating, and it is now being used in a number of stations operating on less than 300 lb. pressure.

The absorption of heat in the feed water by steam extracted from the low-pressure stages of the turbine is much more efficient than is that at the higher stages, because the steam extracted at the low stages has done much more work in the turbine. A high feed temperature means a correspondingly high temperature of the gases leaving the boiler or economizer, which leads to the use of "air economizers" to get the last heat out of the gases where a high feed temperature is used, and if the feed water is heated to within 75 deg. F. of the temperature of saturated steam at the boiler pressure, it is hardly practical to use any water economizer, and a very large air economizer must be used to reduce the temperature of the flue gases to an efficiently low temperature.

Other things being equal, the boiler-plant efficiency depends on the flue-gas temperature; the lower that temperature the higher the efficiency. Approximately 35 deg. F. increase in flue-gas temperature means one per cent loss in plant efficiency, and the comparatively small gain in turbine efficiency by the high-temperature steam extraction — that is, from the high-pressure stages—is likely to be more than can be made up by a commercially practical air economizer. In the writer's opinion, looking at the station efficiency as a whole, the best results will be obtained by using both water and air economizers and a feed temperature somewhere between 220 and 250 deg. F.

The first central station built for high steam pressure

and using reheating, regenerative feed heating and air economizers, was the North Tees Station of the Newcastle Electric Supply Co., which was designed by Merz & McLellan in 1917. There were many delays in the construction of this station on account of war conditions, and it was not put into operation until early in

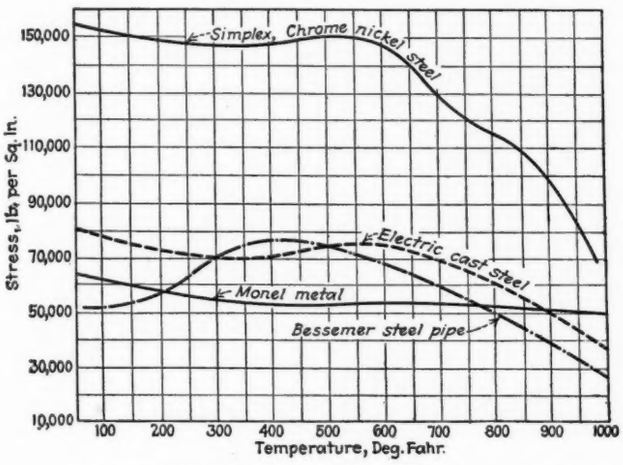


Fig. 3—Ultimate Strength of Metals at High Temperature

1921. The station is equipped with two 20,000-kw. turbines and 10 boilers. The steam is 450 lb. gage and 650 deg. F. In the high-pressure end of the turbine the steam is expanded down to about 65 lb. gage and then conveyed to the interstage superheaters with which five of the boilers are equipped. The steam is reheated to about 500 deg. F. and returned to the turbine. Feed water is heated by steam extraction to 300 deg. F. and each boiler is equipped with an air economizer, but there are no water economizers.

Four power stations are now under construction in the United States which are to use these features for improved economy. The Crawford Avenue Station of the Commonwealth Edison Co., Chicago, and the Philo and Twin Branch Stations of the American Gas & Electric Co. are all to be in operation this year. The Miami Fort Station of the Columbia Power Co. (Cincinnati) is to be in operation next year. In all these stations the steam pressure is to be 550 lb. gage at the turbine throttle and 725 deg. F. initial temperature and reheating at 105 lb. gage pressure to 700 deg. F.

The largest and most important of these stations is the Crawford Avenue Station of the Commonwealth Edison Co. at Chicago. Three turbine units have been ordered for this station: One from C. A. Parsons & Company, Ltd., Newcastle-upon-Tyne, England, of 50,000 kw.; one from the General Electric Co., of 60,000 kw.; and one from the Westinghouse Electric & Manufacturing Co., of 50,000 kw. These are all compound units.

The Parsons unit consists of three separate turbines, a high-pressure turbine running at 1,800 r.p.m. driving a generator of 16,000 kw. capacity, an intermediate at 1,800 r.p.m. driving a 28,000-kw. generator and a low-pressure running at 720 r.p.m. and driving a 6,000-kw. generator. The intermediate and low-pressure turbines are in tandem so that they will look much as though they were one turbine with a generator at each end. All three turbines are "single flow."

The General Electric unit consists of a high-pressure turbine driving an alternator of 17,000-kw. capacity at 1,800 r.p.m. and a low-pressure turbine driving a 43,000-kw. alternator at 1,200 r.p.m. The turbines of this unit have impulse blading throughout and are single flow.

The Westinghouse unit is made up of a high-pressure turbine and an intermediate on one shaft, driving a 20,000-kw. alternator at 1,800 r.p.m., and a double-flow low-pressure turbine driving a 30,000-kw. alternator at 1,800 r.p.m. This unit employs Parsons blading throughout, and the last two rows of blades have a divided exhaust arrangement, a scheme for reducing the length of the low-pressure blades originally developed by K. Baumann, of Manchester, England.

The generators are all of 60 cycles. The low-pressure turbine is in each case equipped with two vertical condensers that stand up adjacent to or at the end of the low-pressure turbine. The vertical condensers are used because with them it is possible to have a very efficient connection between the turbine and condenser and also because the circulating water at the site of this station carries a large amount of sediment which will not foul the vertical tubes.

In each unit the steam is to be reheated after expanding through the high-pressure turbine at about 105 lb. gage from 410 deg. F. The Parsons turbine is designed for heating feed water by steam extraction to 340 deg.

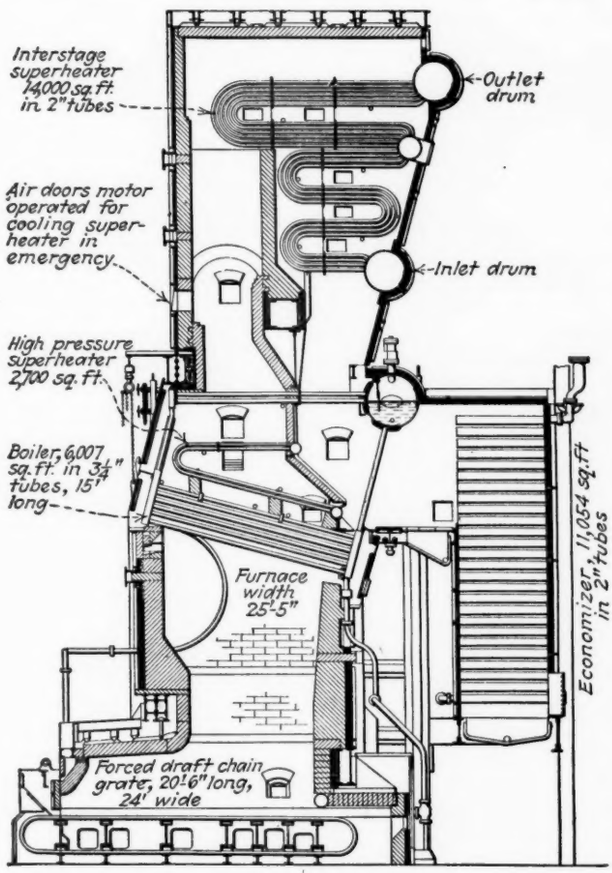

Interstage superheater 14,000 sq. ft. in 2" tubes
Outlet drum
Air doors motor operated for cooling superheater in emergency
Inlet drum
High pressure superheater 2,700 sq. ft.
Boiler, 6,007 sq. ft. in 3¼" tubes, 15' long
Furnace width 25'-5"
Economizer, 11,054 sq. ft. in 2" tubes
Forced draft chain grate, 20'-6" long, 24' wide

Fig. 4—Reheat Boiler, Crawford Avenue Station

F., the General Electric unit to 245 deg. and the Westinghouse to 250 deg. F. The boilers on the Parsons unit will be equipped with both water and air economizers, those on the other units with water economizers only, though air economizers can be added if the expense is proved to be warranted.

There are five boilers on each unit, the one nearest

the turbine in each case being equipped with a reheater. Each of the four "normal boilers" on each unit contains 16,615 sq.ft. of boiler surface. The reheat boiler contains only 6,000 sq.ft. and the reheater containing approximately 41,000 sq.ft. is mounted on top of the boiler. Fig. 4 shows a section of the "reheat boiler." The boiler under the reheater will generate about 65 to 70 per cent as much steam as each of the normal boilers, and is so proportioned that the furnace is the same under both boilers. The stoker under the reheat boiler will be operated so as to regulate the temperature of the actual monthly operating efficiency,—of 88 per cent, which provides for "banked fires" and other "stand-by" losses and for loss of plant efficiency due to irregularities of load, which is a conservative figure for a large plant burning a low grade of coal such as used in Chicago, this plant should average about 15,000 B.t.u. per kilowatt-hour.

As to the cost of these high-pressure stations, it is impractical to make precise comparisons, because two stations cannot be designed and built under exactly similar conditions. Many things affect the cost, such

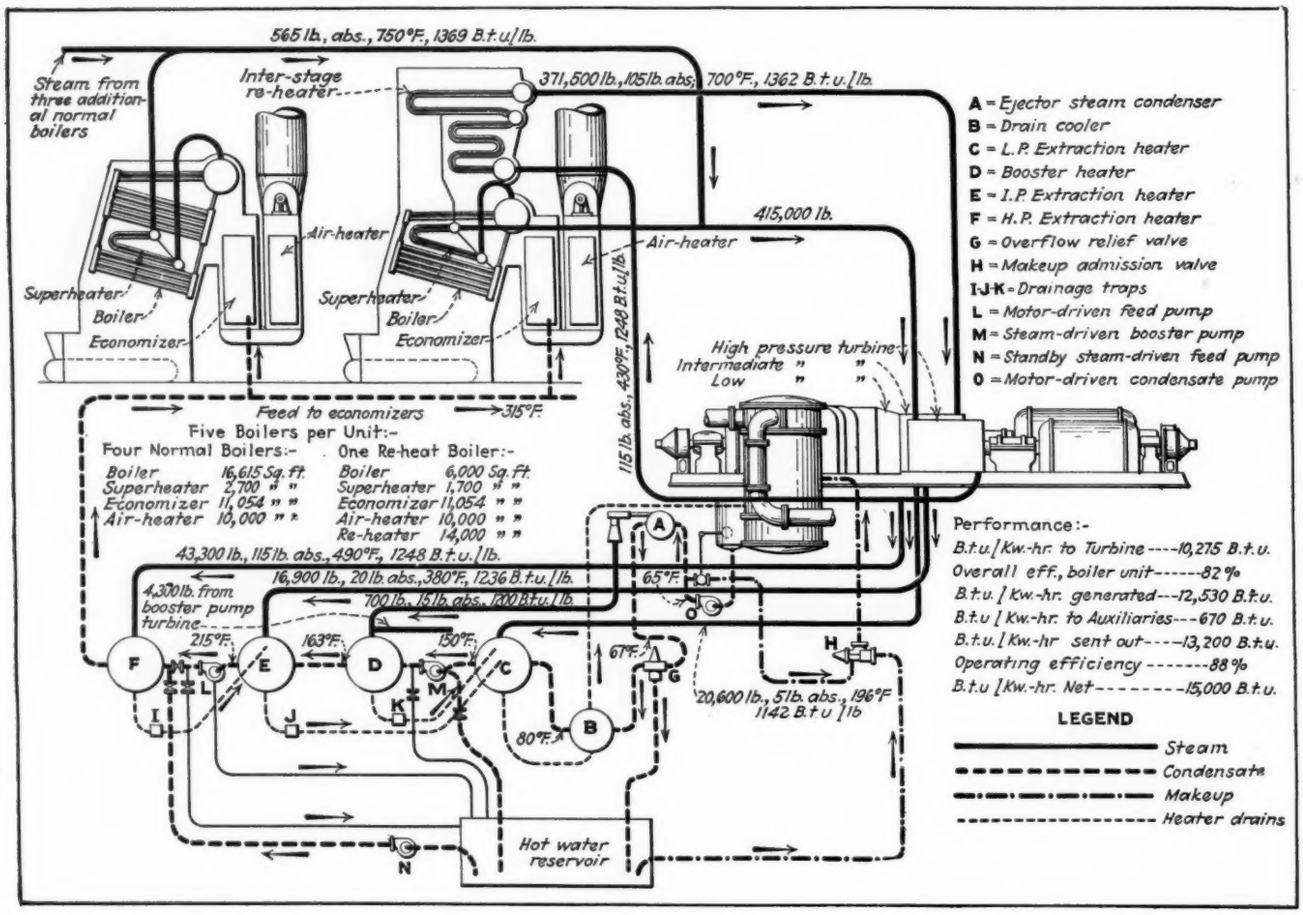


Fig. 5—Performance Diagram of 50,000-kw. Parsons Unit for Crawford Avenue

steam leaving the reheater, and the primary object of the boiler under the reheater is to reduce the temperature of the furnace gases to something under 1,700 deg. F. before they come in contact with the superheater surface, because if tubes containing only dry steam are in direct contact with a temperature as high as that of the furnace, there is likely to be trouble due to the burning of the tubes.

As to the operating efficiency that is to be expected from plants working on a regenerative and reheating cycle such as that of the Crawford Avenue Station, it is obvious that we should expect considerable improvement over the results obtained in the larger stations of today.

In Fig. 5 is shown a "Performance Diagram" of the Parsons unit of the Crawford Avenue Station, and this shows a theoretical fuel consumption at full-load equivalent to 13,210 B.t.u. in the coal per kilowatt-hour. Allowing an "operating efficiency ratio"—that is, the ratio between the theoretical plant efficiency and the as the size of the turbine and boiler units, the character of foundations necessitated by soil conditions, the track layout, coal handling and coal storage, the character of electrical distribution from the station, conditions as to circulating water, the character and quality of building, labor conditions, and other matters of that sort. But fundamentally, the only items that cost more in the high-pressure plants are the turbines, the pressure parts of the boilers and economizers, the live-steam piping, the reheater and reheat piping and the steam-extraction heater system. The turbines cost but little more than in stations for lower pressure. In the boiler plant it is only the pressure parts that cost more, everything else is the same, and the boiler plant as a whole, including the coal-handling equipment, should cost less, because less plant is required in the same ratio as the saving in fuel. The boiler with the reheater costs but little more than the normal boiler and does the same amount of work. The reheat piping and the valves and

the necessary automatic devices are a positive addition to the cost, but the condensing plant should cost less because there is much less steam per kilowatt going to the condensers, and smaller condensers can be used. Taking it altogether, therefore, the plants for 550 lb. pressure should not cost much more than those for 300 lb.

The gain in efficiency of the steam cycle goes up very slowly with increase in pressure above 600 lb. and the auxiliary power increases appreciably owing to the rapid increase in that required by the feed pumps. The reheat problem becomes much more complicated and more expensive. In fact, to get really efficient results with a steam pressure of 1,200 lb. requires reheating twice,

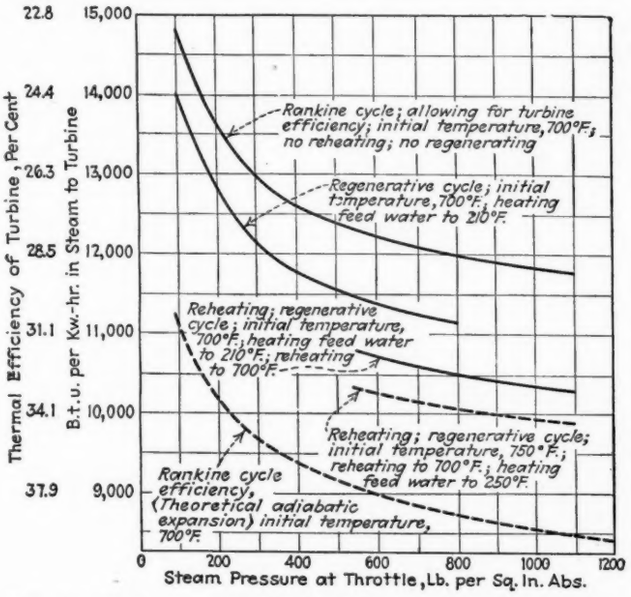


Fig. 6—Turbine-cycle Efficiencies for Various Pressures

first at about 400 lb. and again at about 60 lb. Fig. 6 shows some curves that indicate the improvement in cycle efficiency with increase in steam pressure. No curves such as there shown can be considered exact because the cycle efficiency for any pressure depends upon the amount of steam extraction, the point at which reheating is done and details of that kind, but variations in these factors cannot seriously affect the shape of the curves, which all indicate the slow improvement by increasing steam pressure above 600 lb. Undoubtedly, within a few years, pressures above that will be used in many stations, but the gains in efficiency that can be made by further refinement of the steam cycle will be achieved only by the utmost care in design and the expense will increase rapidly as the pressure goes up.

The famous British engineer, Daniel Kinnear Clark, was ahead of his time. In his book, "Fuel—Its Combustion and Economy," published in 1886, he said, speaking of small H.R.T. furnaces: "The constructing of the furnace chamber so shallow and with such inadequate capacity, appears to have arisen from the idea that the nearer the body to be heated was brought to the source of heat the greater would be the quantity received. Sounder views, however, have shown that it should have been made capacious and the impact of the flame avoided."

Restoring Service After Trouble on a Power System

BY C. M. KING

Some faults on a power system, such as a defective bushing, cannot be burned clear within a reasonable time, and others cannot be burned clear because of the voltage drop between the fault and the generators. In a case observed, a transmission line failed, owing to the breaking of the conductors, in such manner as to cause a three-phase short-circuit 200 miles from the generating station, yet with a voltage of 100,000 at the power house a balanced current of but 300 amperes flowed to the fault. Since the current capacity of this line was 300 amperes, a fault of this nature could hardly be burned clear, and not only may considerable time be required, but several spans of wire may be destroyed during the process, and the system voltage may be so reduced as to preclude the rendering of any kind of service until the trouble is cleared.

SECTIONALIZING THE SYSTEM

Infrequently can a faulty line be switched out manually without at least a partial interruption to service resulting, hence if a system is separated into sections, on any indication of trouble the extent of the interruption can be greatly minimized. One of the most effective and commonly used methods of clearing transmission-system troubles, where relays are not employed, is to sectionalize the system by opening the necessary oil switches on every indication of trouble. Generally, after separating, the trouble will be confined to one section, and the station connected to this section of the system, having what is termed the "right-of-way" over the defective line, either burns the fault clear or isolates the faulty section. When systems are sectionalized, on the occurrence of trouble each station must maintain the frequency and voltage within commercial limits on that section to which it is connected. To permit this, the load allotted to each section must not exceed the capacity of the generating station, keeping in mind that margin must be allowed for governing. After the system is sectionalized, it is customary to synchronize all sections but the faulty one as quickly as possible, for the demands for power can generally be best supplied by operating the sections in parallel.

Supposing that a transmission system has been quickly sectionalized because of the occurrence of trouble, conditions will soon become normal at all generating stations except the one connected to the faulty line. Assuming that the trouble has been caused by two conductors of a three-phase line making permanent contact, considerable current would flow unless the impedance was of an unusually high value. If so, the line current, while unbalanced, might not exceed the full-load value, and the fault, assumed to be of a permanent nature, could not be burned clear within a reasonable time. In this case the operator would probably greatly reduce the generator voltage and cut out the faulty line by opening the line oil switch. After having a line sectionalizing switch opened, usually the one most distant from the generating station, a test would be made by connecting one generator, at very low voltage, to the line, then increasing the voltage to the no-load value, if the ammeters gave a normal indication, or by connecting the line to the bus on which all the

generators are operating, without taking time to separate a unit for testing purposes. If a faulty line is connected to a station bus, it is likely that the generators connected thereto will be thrown out of synchronism, and considerable time may be required to bring them into step, even after the defective line is switched out. For this reason and to limit the short-circuit current and its possibly harmful effects, a faulty transmission line is usually tested with but one generator.

Testing Transmission Line

When spare generating capacity is available, it is always good practice to test a transmission line after any work, such as meggering or changing insulators, has been done. This eliminates the possibility of connecting a line that may have become faulty since being taken out of service, or to which grounding or short-circuiting devices have been accidentally left connected. On a few systems where synchronous condensers are used, motors are employed to drive the condensers as generators, so that transmission lines may be tested from substations, through step-up transformers, without disturbance to the system.

Instead of depending on manual operation for sectionalizing transmission systems, relays which function on the occurrence of low voltage are sometimes employed, with generally favorable results. The automatic separating device used on one system utilizes a contact-making voltmeter, the contacts of which, when closed, energize a relay switch, which applies, through several carbon contacts, current to the trip coils of a number of oil switches. The winding of the contact-making voltmeter is generally such that the device will function when the voltage decreases to 80 per cent of the full-load value. Such a separating device as this or voltage relays such as those made by several manufacturers, can sometimes be used to advantage to sectionalize systems or buses when a fault develops. Where such a relay is used, care must be taken to disconnect it before the circuit to which it is connected is de-energized and to be certain that the voltage, on the occurrence of a fault, will be reduced to the point at which the relay is set to function.

Using the Ammonia Tables

By John E. Starr

Engineers in charge of refrigerating plants do not make as much use of the properties of ammonia tables as they should. There is nothing mysterious about these tables, and they are valuable aids to the engineer who is trying to obtain results in the plant.

The Bureau of Standards, Washington, D. C., has issued Circular No. 142, which contains tables giving the properties of both saturated and superheated ammonia. Part of the saturated-ammonia table is here reproduced as Table I. The tables originally gave only the pounds per square inch in terms of absolute pressure. Engineers are so accustomed to figure in terms of gage pressure that column 3, giving the gage pressure, was added; the gage readings up to 14.7 lb. absolute are in terms of inches of mercury.

Even the most inexperienced of engineers need not be alarmed at the column headings. After once understood, the table will be found of great assistance.

For example if the gage pressure reads 15 lb., this value in the third column under the heading "g.p." will be found opposite —1 under the heading "Temp. °F" in column 1. This indicates that this temperature, —1 deg. F., is the evaporating temperature of ammonia under 15 lb. gage pressure.

Under "Volume Vapor" in column 4 it will be seen that a pound of ammonia vapor at this temperature and pressure will occupy 9.326 cu.ft., and column 5 reveals that a cubic foot of the vapor will weigh 0.1072 pound.

A pound of liquid requires 41.8 B.t.u. to raise it to —1 deg. from —40 deg. F., at which latter point it is assumed for convenience that the ammonia has no

TABLE I—PROPERTIES OF SATURATED AMMONIA

Temp. °F.	Pressure. Absolute. lbs./in.²	Pressure. Gage. lbs./in.	Volume vapor. ft.³/lb.	Density vapor. lbs./ft.³	Heat content. Liquid. Btu./lb.	Heat content. Vapor. Btu./lb.	Latent heat. Btu./lb.	Entropy. Liquid. Btu./lb.°F.	Entropy. Vapor. Btu./lb.°F.
t	*p*	*g. p.*	*V*	*1/V*	*h*	*H*	*L*	*s*	*S*
−40	10.41	*8.7	24.86	0.04022	0.0	597.6	597.6	0.0000	1.4242
−39	10.72	*8.1	24.18	.04135	1.1	598.0	596.9	.0025	.4217
−38	11.04	*7.4	23.53	.04251	2.1	598.3	596.2	.0051	.4193
−37	11.37	*6.8	22.89	.04369	3.2	598.7	595.5	.0076	.4169
−36	11.71	*6.1	22.27	.04489	4.3	599.1	594.8	.0101	.4144
−35	12.05	*5.4	21.68	0.04613	5.3	599.5	594.2	0.0126	1.4120
−34	12.41	*4.7	21.10	.04739	6.4	599.9	593.5	.0151	.4096
−33	12.77	*3.9	20.54	.04868	7.4	600.2	592.8	.0176	.4072
−32	13.14	*3.2	20.00	.04999	8.5	600.6	592.1	.0201	.4048
−31	13.52	*2.4	19.48	.05134	9.6	601.0	591.4	.0226	.4025
−30	13.90	*1.6	18.97	0.05271	10.7	601.4	590.7	0.0250	1.4001
−29	14.30	*0.8	18.48	.05411	11.7	601.7	590.0	.0275	.3978
−28	14.71	0.0	18.00	.05555	12.8	602.1	589.3	.0300	.3955
−27	15.12	0.4	17.54	.05701	13.9	602.5	588.6	.0325	.3932
−26	15.55	0.8	17.09	.05850	14.9	602.8	587.9	.0350	.3909
−25	15.98	1.3	16.66	0.06003	16.0	603.2	587.2	0.0374	1.3886
−24	16.42	1.7	16.24	.06158	17.1	603.6	586.5	.0399	.3863
−23	16.88	2.2	15.83	.06317	18.1	603.9	585.8	.0423	.3840
−22	17.34	2.6	15.43	.06479	19.2	604.3	585.1	.0448	.3818
−21	17.81	3.1	15.05	.06644	20.3	604.6	584.3	.0472	.3796
−20	18.30	3.6	14.68	0.06813	21.4	605.0	583.6	0.0497	1.3774
−19	18.79	4.1	14.32	.06985	22.4	605.3	582.9	.0521	.3752
−18	19.30	4.6	13.97	.07161	23.5	605.7	582.2	.0545	.3729
−17	19.81	5.1	13.62	.07340	24.6	606.1	581.5	.0570	.3708
−16	20.34	5.6	13.29	.07522	25.6	606.4	580.8	.0594	.3686
−15	20.88	6.2	12.97	0.07709	26.7	606.7	580.0	0.0618	1.3664
−14	21.43	6.7	12.66	.07898	27.8	607.1	579.3	.0642	.3643
−13	21.99	7.3	12.36	.08092	28.9	607.5	578.6	.0666	.3621
−12	22.56	7.9	12.06	.08289	30.0	607.8	577.8	.0690	.3600
−11	23.15	8.5	11.78	.08490	31.0	608.1	577.1	.0714	.3579
−10	23.74	9.0	11.50	0.08695	32.1	608.5	576.4	0.0738	1.3558
−10	23.74	9.0	11.50	0.08695	32.1	608.5	576.4	0.0738	1.3558
−9	24.35	9.7	11.23	.08904	33.2	608.8	575.6	.0762	.3537
−8	24.97	10.3	10.97	.09117	34.3	609.2	574.9	.0786	.3516
−7	25.61	10.9	10.71	.09334	35.4	609.5	574.1	.0809	.3495
−6	26.26	11.6	10.47	.09555	36.4	609.8	573.4	.0833	.3474
−5	26.92	12.2	10.23	0.09780	37.5	610.1	572.6	0.0857	1.3454
−4	27.59	12.9	9.991	.1001	38.6	610.5	571.9	.0880	.3433
−3	28.28	13.6	9.763	.1024	39.7	610.8	571.1	.0904	.3413
−2	28.98	14.3	9.541	.1048	40.7	611.1	570.4	.0928	.3393
−1	29.69	15.0	9.326	.1072	41.8	611.4	569.6	.0951	.3372
0	30.42	15.7	9.116	0.1097	42.9	611.8	568.9	0.0975	1.3352
1	31.16	16.5	8.912	.1122	44.0	612.1	568.1	.0998	.3332
2	31.92	17.2	8.714	.1148	45.1	612.4	567.3	.1022	.3312
3	32.69	18.0	8.521	.1174	46.2	612.7	566.5	.1045	.3292
4	33.47	18.8	8.333	.1200	47.2	613.0	565.8	.1069	.3273
5	34.27	19.6	8.150	0.1227	48.3	613.3	565.0	0.1092	1.3253
6	35.09	20.4	7.971	.1254	49.4	613.6	564.2	.1115	.3234
7	35.92	21.2	7.798	.1282	50.5	613.9	563.4	.1138	.3214
8	36.77	22.1	7.629	.1311	51.6	614.3	562.7	.1162	.3195
9	37.63	22.9	7.464	.1340	52.7	614.6	561.9	.1185	.3176
70	128.8	114.1	2.312	0.4325	120.5	629.1	508.6	0.2537	1.2140
71	131.1	116.4	2.273	.4399	121.7	629.3	507.6	.2558	.2125
72	133.4	118.7	2.235	.4474	122.8	629.4	506.6	.2579	.2110
73	135.7	121.0	2.197	.4551	124.0	629.6	505.6	.2601	.2095
74	138.1	123.4	2.161	.4628	125.1	629.8	504.7	.2622	.2080
75	140.5	125.8	2.125	0.4707	126.2	629.9	503.7	0.2643	1.2065
76	143.0	128.3	2.089	.4786	127.4	630.1	502.7	.2664	.2050
77	145.4	130.7	2.055	.4867	128.5	630.2	501.7	.2685	.2035
78	147.9	133.2	2.021	.4949	129.7	630.4	500.7	.2706	.2020
79	150.5	135.8	1.988	.5031	130.8	630.5	499.7	.2728	.2006
80	153.0	138.3	1.955	0.5115	132.0	630.7	498.7	0.2749	1.1991
81	155.6	140.9	1.923	.5200	133.1	630.8	497.7	.2769	.1976
82	158.3	143.6	1.892	.5287	134.3	631.0	496.7	.2791	.1962
83	161.0	146.3	1.861	.5374	135.4	631.1	495.7	.2812	.1947
84	163.7	149.0	1.831	.5462	136.6	631.3	494.7	.2833	.1933
85	166.4	151.7	1.801	0.5552	137.8	631.4	493.6	0.2854	1.1918
85	166.4	151.7	1.801	0.5552	137.8	631.4	493.6	0.2854	1.1918
86	169.2	154.5	1.772	.5643	138.9	631.5	492.6	.2875	.1904
87	172.0	157.3	1.744	.5735	140.1	631.7	491.6	.2895	.1889
88	174.8	160.1	1.716	.5828	141.2	631.8	490.6	.2917	.1875
89	177.7	163.0	1.688	.5923	142.4	631.9	489.5	.2937	.1860
90	180.6	165.9	1.661	0.6019	143.5	632.0	488.5	0.2958	1.1846
91	183.6	168.9	1.635	.6116	144.7	632.1	487.4	.2979	.1832
92	186.6	171.9	1.609	.6214	145.8	632.2	486.4	.3000	.1818
93	189.6	174.9	1.584	.6314	147.0	632.3	485.3	.3021	.1804
94	192.7	178.0	1.559	.6415	148.2	632.5	484.3	.3041	.1789

heat. This is found in column 6 under the heading "Liquid B.t.u."

The heat of the liquid at 178 lb. gage is given as 148.2, and since it was 41.8 at —1 deg., 148.2 — 41.8 = 106.4 B.t.u. must be removed from a pound of liquid ammonia at 178 lb. gage pressure and 94 deg. temperature to reduce it to —1 deg. F. If we cool a pound of water, we must remove 1 B.t.u. for each deg. it is cooled, so it is apparent that we must take a little more heat out of ammonia than out of water to cool it a stated number of degrees.

In colmun 7 under the heading "Vapor B.t.u./lb." are given the amounts of heat a pound of ammonia vapor will have at any pressure. At 15 lb. gage and —1 deg. F. the ammonia vapor will contain 611.4 B.t.u.; this consists of the heat necessary to raise the liquid from —40 to —1 deg., or 41.8 B.t.u. plus the heat needed to vaporize the liquid, or 569.6 B.t.u. This latter heat, 569.6 B.t.u., will be found in column 8 under "Latent Heat."

The columns giving the "entropy" need not concern us now since these factors are used only in calculations not dealt with here.

The superheat tables are given in terms of absolute pressure, but for practical use zero gage may be taken as 15 lb. absolute. The heading in heavy type, Table II, is lb. per sq.in. absolute. Below the pressure value is given the evaporating temperature, which in case of 30 lb. absolute is —0.57 deg., or approximately —1 deg.

As an example of how to use the superheat table, assume that the pressure is 30 lb. absolute (15 lb. gage) and the thermometer reading is 20 deg. Since the boiling point at this pressure is —1 deg. F., this means that the gas is superheated 21 deg. When in this condition the superheated vapor or gas contains 623.5 B.t.u. per pound as indicated by the figure in the column under the heading *H* in line with 20 deg. Its volume, as shown by the value in the column headed *V* is 0.731 cu.ft. per pound.

If the gage on the suction side of the compressor shows 15 lb. and there is no choke in the coil, one knows the boiling temperature in the coil is 1 deg. below zero, as shown by Table I. If a thermometer in the suction line shows 20 deg. F., one may be confident that the system is choked somewhere between the compressor and coil inlet.

The volume of a pound of vapor at the temperature it leaves the liquid is seldom as much as the actual volume handled by the compressor per pound evaporated. In the first place it is likely to be superheated a little on its way to the compressor by picking up heat in the suction line. The heat so taken up of course does nobody any good, but is usually so small that it is neglected. With most plants it does not affect the results adversely more than 2 per cent. A superheat of, say, 10 deg. may be tolerated. A glance at the tables readily puts one in position to figure just what it amounts to in any case.

As it enters the compressor the gas is further heated by heat absorbed from the cylinder and further swelled in volume. So the compressor volume per pound of ammonia is always more than the evaporator volume. The same considerations apply to the superheat at the head pressure. It will always be an item but seldom an item that can be reduced below a certain point. It is arrived at by adding together the total heat of the gas at the evaporator and the heat corresponding to the power used in the compressing of the charge. The result is the total heat that one pound should have as the gas leaves the compression valves, and a look at the superheat tables shows at once what the temperatures of the outlet gas should be. If they are higher than they should be, it is time to look for trouble in the discharge end of the compressor; generally the discharge valves are found to be in bad shape.

Here is where the column "entropy" marked *S* in the superheat tables comes into play. If there is no heat lost to the cylinder walls by the gas during compression and none absorbed by the gas from the cylinder or suction valves, the entropy remains constant. If the suction pressure is 30 lb. absolute (15 lb. gage) and the suction temperature 20 deg. F., indicating a slight superheat, then the entropy is 1.3618. Suppose the discharge pressure is 170 lb. absolute (155 lb. gage). By looking in the table under 170 lb. absolute gas, we find that at a temperature of 260 deg. the entropy is 1.3679, while at 250 deg. it is 1.3596, so that for an entropy of 1.3618 the temperature should be 254 deg. If the thermometer indicates 300 deg., one may be certain that there is a lot of heating at the suction valve or it may be caused by a leaking piston, permitting the hot gas to blow by to be recompressed on the next stroke.

A familiarity with the tables of ammonia properties is an asset to any refrigerating-machine operator, as it will assist him in the every-day operation of the plant.

TABLE II—PROPERTIES OF SUPERHEATED AMMONIA

[V = volume in ft.³/lb.; H = heat content in Btu./lb.; S = entropy in Btu./lb. °F.]

Temp. °F.	Absolute pressure in lbs./in.² (Saturation temperature in italics.) 30 *—0.57°*			31 *+0.79°*			32 *+2.11°*			Temp. °F.
	V	*H*	*S*	*V*	*H*	*S*	*V*	*H*	*S*	
Sat.	*9.830*	*611.6*	*1.3377*	*9.565*	*612.0*	*1.3336*	*9.308*	*612.4*	*1.3310*	*Sat.*
10	9.492	617.8	1.3497	9.173	617.4	1.3453	8.874	617.1	1.3411	10
20	9.731	623.5	.3618	9.405	623.2	.3574	9.099	622.9	.3532	20
30	9.966	629.1	.3733	9.633	628.8	.3691	9.321	628.5	.3649	30
40	10.20	634.6	.3845	9.858	634.4	.3803	9.540	634.1	.3762	40
50	10.43	640.1	1.3953	10.08	639.9	1.3912	9.757	639.6	1.3871	50
60	10.65	645.5	.4059	10.30	645.3	.4017	9.972	645.1	.3977	60
70	10.88	650.9	.4161	10.52	650.7	.4120	10.18	650.5	.4080	70
80	11.10	656.2	.4261	10.74	656.1	.4221	10.40	655.9	.4181	80
90	11.33	661.6	.4359	10.96	661.4	.4319	10.61	661.2	.4280	90
100	11.55	666.9	1.4456	11.17	666.7	1.4415	10.81	666.6	1.4376	100
110	11.77	672.2	.4550	11.38	672.1	.4510	11.02	671.9	.4470	110
120	11.99	677.5	.4642	11.60	677.4	.4602	11.23	677.3	.4563	120
130	12.21	682.9	.4733	11.81	682.7	.4693	11.44	682.6	.4655	130
140	12.43	688.2	.4823	12.02	688.1	.4783	11.64	687.9	.4744	140
150	12.65	693.5	1.4911	12.23	693.4	1.4871	11.85	693.3	1.4833	150
160	12.87	698.8	.4998	12.44	698.7	.4958	12.05	698.6	.4920	160
170	13.08	704.2	.5083	12.66	704.1	.5044	12.26	704.0	.5006	170
180	13.30	709.6	.5168	12.87	709.5	.5129	12.46	709.4	.5090	180
190	13.52	714.9	.5251	13.07	714.8	.5212	12.66	714.7	.5174	190
200	13.73	720.3	1.5334	13.28	720.2	1.5294	12.86	720.1	1.5256	200
220	14.16	731.1	.5495	13.70	731.1	.5456	13.27	731.0	.5418	220
240	14.59	742.0	.5653	14.12	742.0	.5614	13.67	741.9	.5576	240
260	15.02	753.0	.5808	14.53	752.9	.5769	14.08	752.9	.5731	260
280	15.45	764.1	.5960	14.95	764.0	.5921	14.48	763.9	.5883	280
	150 *78.81°*			**160** *89.64°*			**170** *99.99°*			
Sat.	*1.594*	*630.5*	*1.3009*	*1.378*	*631.1*	*1.3968*	*1.784*	*631.6*	*1.1900*	*Sat.*
90	2.061	638.8	1.2161	1.914	636.6	1.2055	1.784	634.4	1.1952	90
100	2.118	645.9	1.2289	1.969	643.9	1.2186	1.837	641.9	1.2087	100
110	2.174	652.8	.2410	2.023	651.0	.2311	1.889	649.1	.2215	110
120	2.228	659.4	.2526	2.075	657.8	.2429	1.939	656.1	.2336	120
130	2.281	665.9	.2638	2.125	664.4	.2542	1.988	662.8	.2452	130
140	2.334	672.3	.2745	2.175	670.9	.2652	2.035	669.4	.2563	140
150	2.385	678.6	1.2849	2.224	677.2	1.2757	2.081	675.9	1.2669	150
160	2.435	684.8	.2949	2.272	683.5	.2859	2.127	682.3	.2773	160
170	2.485	690.9	.3047	2.319	689.7	.2958	2.172	688.5	.2873	170
180	2.534	696.9	.3142	2.365	695.8	.3054	2.216	694.7	.2971	180
190	2.583	702.9	.3236	2.411	701.9	.3148	2.260	700.8	.3066	190
200	2.631	708.9	1.3327	2.457	707.9	1.3240	2.303	706.9	1.3159	200
210	2.679	714.8	.3416	2.502	713.9	.3331	2.346	713.0	.3249	210
220	2.726	720.7	.3504	2.547	719.9	.3419	2.389	719.0	.3338	220
230	2.773	726.6	.3590	2.591	725.8	.3506	2.431	724.9	.3426	230
240	2.820	732.5	.3675	2.635	731.7	.3591	2.473	730.9	.3512	240
250	2.866	738.4	1.3758	2.679	737.6	1.3675	2.514	736.8	1.3596	250
260	2.912	744.3	.3840	2.723	743.5	.3757	2.555	742.8	.3679	260
270	2.958	750.1	.3921	2.766	749.4	.3838	2.596	748.7	.3761	270
280	3.004	756.0	.4001	2.809	755.3	.3919	2.637	754.6	.3841	280
290	3.049	761.8	.4079	2.852	761.2	.3998	2.678	760.5	.3921	290
300	3.095	767.7	1.4157	2.895	767.1	1.4076	2.718	766.4	1.3999	300
320	3.185	779.4	.4310	2.980	778.9	.4229	2.798	778.3	.4153	320
340	3.274	791.2	.4459	3.064	790.7	.4379	2.878	790.1	.4303	340

The Protection of Steam-Turbine Disks from Axial Vibration

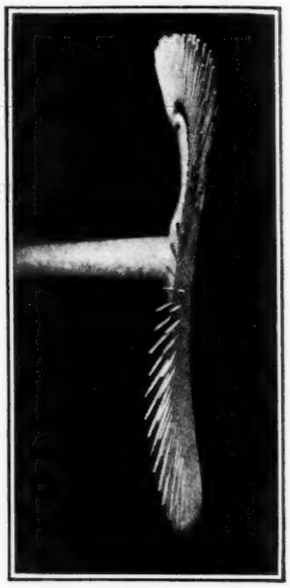


Fig. 1—Rubber disk (retouched)

ON ACCOUNT of the rapid increase in turbine capacities during the war period, the mechanical possibilities were pushed to the utmost. The use of single-row bucket wheels and high velocities led to larger diameter disks. Turbine failures of an erratic nature proved to be caused by fatigue effects of backward traveling waves.

IN ORDER to account for turbine wheel failures of a peculiar and erratic nature, which could not be explained on the basis of stress alone, the General Electric Company has made an elaborate investigation. This is the subject of the paper presented by the late Wilfred Campbell at the spring meeting of the American Society of Mechanical Engineers, Cleveland, Ohio, May 26-29, 1924, of which this is an abstract. The essential cause was found to be fatigue resulting from disk vibration whose period corresponded closely to the turbine operating speed. This has been obviated by building disks with critical vibrating periods removed by safe margins from the operating speed.

Vibration taking place in turbine disks includes forward traveling waves, backward traveling and stationary waves, the latter consisting of the two previous varieties in combination. If the description given in Mr. Campbell's paper were condensed to the space here allowed, the explanations would fall short of their true value. In order to conform to these limits, a note appears at the end of this article wherein these and other conditions are briefly compared to familiar examples, which it is hoped will supply an equally clear conception of these phenomena.

No special difficulties have been encountered with regard to turbine wheel vibration, which would indicate that the changes of design, made during and previous to the war, would produce unsatisfactory results. A rapid increase of turbine capacities at this period made it necessary to adopt greater bucket speeds and hence larger wheel diameters. Turbine wheels, containing single bucket rows, were utilized throughout for steam turbines long before. Light wheels were desired on account of obtaining minimum stress at the bore and less weight on the shaft as dictated by the unquestioned advantages of a rigid shaft and lower stresses generally.

With the sudden increase of capacity the mechanical possibilities were pushed to the limit. Greater capacity, on the other hand, due to an advance in thermal conditions, did not occur until later and is still going on.

After the investigation, which was begun in 1919, had been sufficiently advanced, wheels in turbines were tested for vibration. Up to March 1, 1924, there was a total of 4,399 wheels installed on machines over 5,000 kw. in capacity. Of these 3,596 were tested standing and 497 were replaced to avoid further trouble.

Waves were studied by the utilization of thin disks of steel or rubber. In Fig. 1 appears a retouched photograph of waves actually occurring in a rotating thin rubber disk. These ordinarily are backward traveling waves. In Fig. 2 sand figures indicate waves produced by an electromagnet, which vibrates the disk. Sand placed on the wheel is thrown from the actively vibrating sections into those that are quiet. This represents standing vibration, in which each node or vibrating area is stationary with regard to the wheel. As explained in

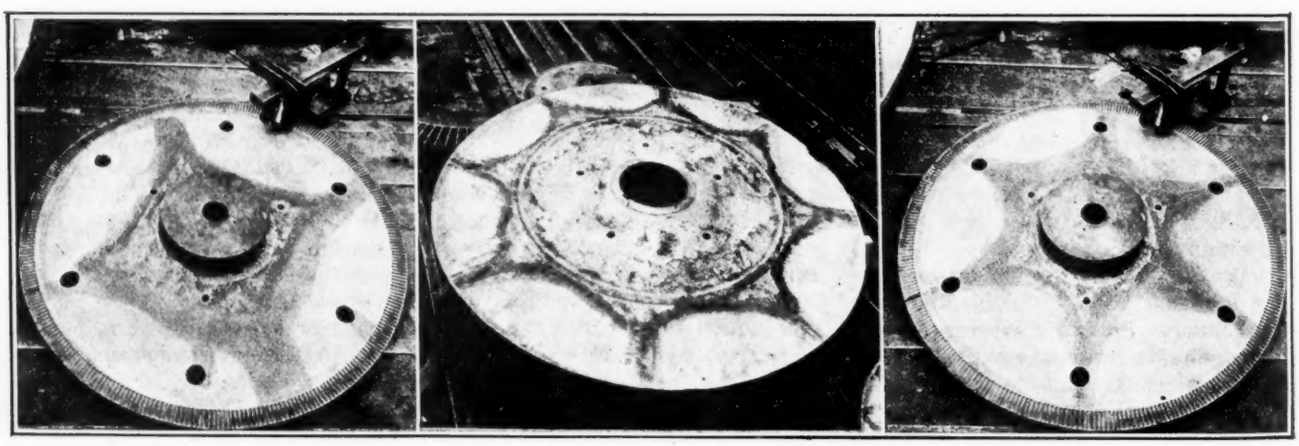


Fig. 2—Four-node standing wave produced by magnetic pulls

Fig. 3—Eight-node wave vibrates principally at buckets

Fig. 4—Six-node vibration at higher frequency than 4-node

the appended note, this really consists of two trains of waves traveling in both directions around the disk. Actually, one wave travels to the right and the other to the left, at equal displacements.

If the frequency of the magnetic action is raised sufficiently, 6-node vibration will develop as indicated in Fig. 4. It is not necessarily dependent on the position of the balancing holes. Waves of 8, 10, 12, or even a larger number of nodes may be produced by increasing the magnet frequency. When long buckets are present, the vibrating frequency is largely influenced by the mass and other conditions of the buckets themselves, as in Fig. 3, the wheel shown being over 8 ft. in total diameter. Paper has been laid over the buckets in order to support the sand. This represents an 8-node vibration, and the quiet area includes the entire disk, so that the buckets principally vibrate at this frequency. With lower frequencies, such as 4-node, it will be noted that the quiet areas are much closer to the hub.

Two-node vibration has not so far been known as a stationary wave. In this case, where one side moves up the other moves down, forces are thus exerted on the shaft. With a larger number of nodes, however, the forces are practically balanced, so that the shaft is not greatly affected.

A machine for mechanically vibrating a wheel, Fig. 7, consists of an electric motor attached by a connecting rod to a vertical reciprocating lever. The lower end of this lever is pivoted, and the pivot is held between springs so it may move. In between the ends of this reciprocating lever is attached a rod that communicates the reciprocating motion to the shroud band. At a critical vibrating speed the pivot is practically stationary but at other points the wheel moves little and the pivot moves instead between the spring supports. A compressed-air turbine is preferred to the electric motor for use in the field. A tachometer indicates speed.

At *A*, Fig. 5, is shown the tracing of an oscillogram produced by two stationary coils 30 deg. apart, and also that of a 25-cycle timing wave. The coil making the upper curve leads as to location, so that a point on the wheel reaches it before the coil of the lower curve. In the diagram, however, the waves are moving toward the left, and a high point on the lower curve is actually ahead of a similar point on the upper, indicating a backward wave. From measurements of the wave forms, calculations show that the wheel carries a 6-node backward traveling wave, $31\frac{5}{4}$ r.p.s., with respect to the wheel which itself rotates only 25 r.p.s., and also a forward traveling wave about nine times as fast. The wheel giving the five oscillograms in this figure is from the 17th stage of a 20,000-kw. 1,500-r.p.m. 23-stage turbine.

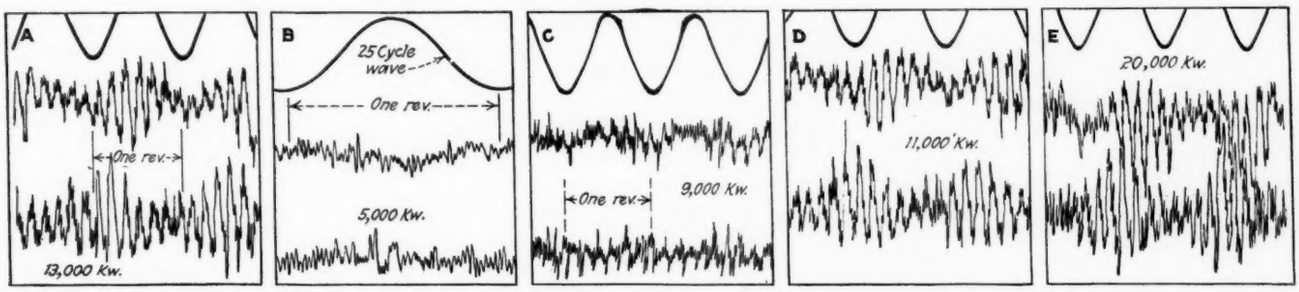


Fig. 5—Two stationary coils 30 deg. apart show backward wave at A, *smooth running at* B *and increased vibration at higher loads,* C, D *and* E *(traced)*

Figures *B*, *C* and *D* indicate the differences of vibration in the same disk as produced by load variation. The record of a smoothly running disk is indicated in *B*, at 5,000 kw. At a load of 9,000, as shown at *C*, wave motion has not yet greatly developed. With 11,000 kw. as at *D*, wave motion is fully developed, and at *E*, the final record, representing 20,000 kw., it is still farther advanced.

Tests with buckets mounted on flexible disks when vibrating indicate that air or steam ejected from a nozzle presents varying thrusts on the buckets due to their twisting or changes of angles with regard to the nozzle stream. Backward waves could thus be increased until they are sufficient to rub the nozzles. This is called a "feathering action" and is the cause of increased vibration in Fig. 5.

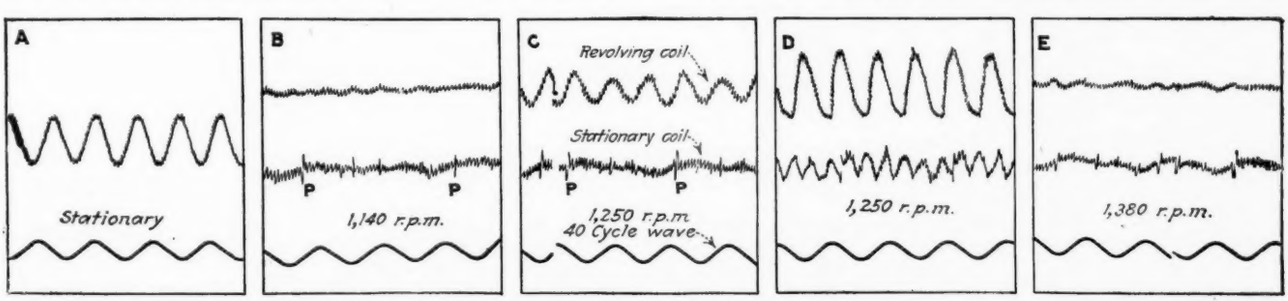


Fig. 6—Stationary and moving coils show vibration. At A, *standing wave;* B *smooth running autograph;* C *and* D, *6-node critical speed and at* E, *good operation (traced)*

Figure 6 represents the effect of speed in producing critical vibration where the natural period of the disk oscillation corresponds to a turbine speed of 1,250 r.p.m. The wheel is stationary at *A*, the upper record representing that of a stationary coil, and the lower a timing wave when the wheel is vibrated mechanically in 6-node vibration.

At 1,140 r.p.m., no vibration is noted as at *B*, this being the wheel "autograph," but at *C*, where the disk rotates 1,250 r.p.m., which is the 6-node critical speed, the revolving coil shows a backward wave in the wheel. The stationary coil is opposite a wave stationary in space. In *D* at the same speed a moment later, the waves have developed somewhat more with a forward

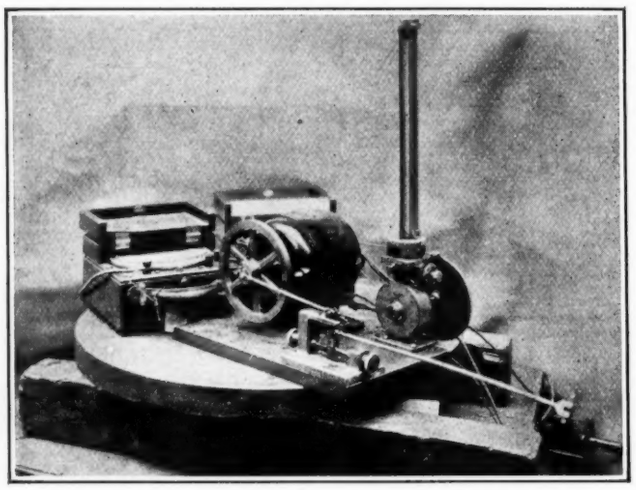


Fig. 7—Electrically driven machine vibrates turbine disks

wave on the stationary coil. At *E* the critical disk speed of 1,250 r.p.m. has been passed and the vibration has vanished. One revolution is represented between the points *P P*.

Centrifugal force tends to stiffen the disk and therefore to raise the period of disk vibration, as explained in the note following this article. In Fig. 10 the record of a moving coil shows the increase of frequency of disk vibration as the speed is raised. The frequency of the forward traveling wave is raised while the backward traveling wave, which exists along with the forward one to make up a stationary wave, has its frequency reduced, as shown. The following formulas show these relations:

$$F_r = \sqrt{F_s^2 + B N_s^2};\ H = F_r + \frac{n}{2} N_s;\ M = F_r - \frac{n}{2} N_s$$

The frequency F_r is recorded in the revolving coil, at the speed N_s, representing the combined or standing wave; *H*, the frequency of the forward wave in r.p.s., as given by the stationary coil, and *M* that of the backward wave from the same coil. F_s is the frequency of the standing wave produced on a stationary disk. N_s is the revolutions per second of the wheel, and n the number of nodes making up the complete wave surrounding the wheel. *B* is a constant or speed coefficient depending on the design of the wheel and type of vibration. This is generally from 2 to 3, being lower when the quiet areas are restricted closely to the hub.

The effects of fatigue due to disk vibration are indicated in Figs. 8 and 9. In the latter a crack has occurred which was discovered in time to prevent damage. The upper figure shows the effect of a crack that was allowed to develop so as to cause failure. Fatigue, similarly, may cause failure of buckets or rims.

Fatigue has been exhaustively investigated. The power required to produce this in 6- and 4-node vibration, which is easily measured with an electric vibrating machine, is shown in Fig. 11. This indicates that the energy dissipated is comparatively small. In Fig. 12 the energy required for both traveling and stationary waves shows that the former are produced with less energy, but the latter are more readily developed at amplitudes greater than that at the point *P*.

The effect of forced rubbing on vibration was investigated with a result that vibration of an erratic character was produced by a shoe thrust against the rim of the wheel. When running at a lower or minor critical speed, a well-formed backward traveling wave may occur, but at any other point the wave is very erratic. The effect of heating the hub with a gas flame to about 200 deg. F. warmer than the rim was tried, with the result that there are only slight changes in 2- and 4-node frequencies, although greater differences are noted with 6 and 8 nodes. In actual operation the temperature differences are not anything like these tests, and sufficient margin for such temperature differences has been allowed for in the design of the buckets.

Tightness of the buckets influences vibration appreciably. A considerable difference in 2-node frequency is thus produced with smaller differences in other types of vibration. Calking the buckets in order to tighten them makes large changes in the critical speed. Standing vibration is changed appreciably by replacing the buckets in a loose condition, although this did not affect the running tests greatly.

The margins of speed that should be allowed between the operating speeds and those of critical disk vibration are determined from several considerations. In the first place a critical or resonant disk speed is not located or confined by a matter of one or two revolutions. The vibration may occur at a speed slightly above critical or slightly below. Special tests have shown that this

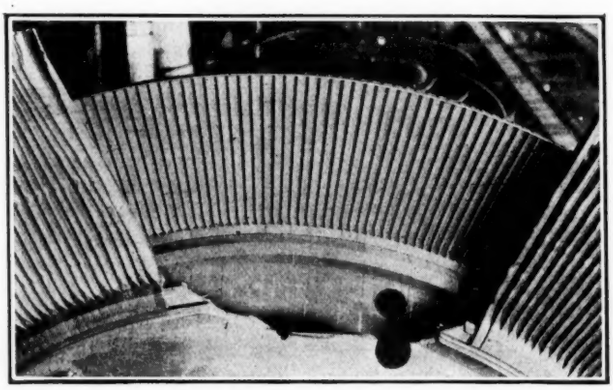


Fig. 8—Fatigue crack developed into fracture

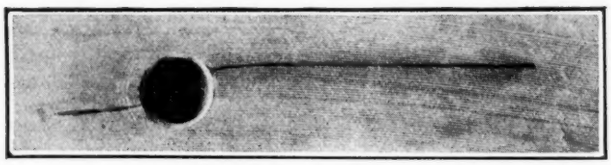


Fig. 9—Disk fissure starts in tapped hole

broadness of resonance amounts to about 2 per cent above and below a critical speed.

Another possibility is the variation in the operating speed of the turbine at the plant as system frequencies may vary appreciably. The coefficient *B* in the formula for determining a disk critical running speed is obtained from a number of tests of similar wheels, and to a certain extent is approximate. Temperature variations in the disk also may change the resonant speed.

Investigations of the subject have led to the conclusion that 6- or 8-node vibration should be separated by a margin of at least 10 per cent either above or below the operating speed. Four-node critical speeds should require 15 per cent separation. In addition, wheels are not accepted which show 10-node and 12-node, critical speeds that are appreciably close to that of turbine operation, although other requirements may have been met.

The critical vibration speed may be readily adjusted through mechanical means. As mentioned in the note, following this article, the frequency of vibration may be raised by removing weight from the periphery of a disk or by increasing its stiffness. This resonant speed may be lowered by a similar adjustment in the opposite direction.

In order to insure that the turbine wheels are protected by ample margins of safety, a number of steps, involving assumption, design, checking and perhaps the redesign and repetition of the preceding steps are required in their design and manufacturing routine, which are as follows:

1. The bucket is first selected in accordance with thermodynamic requirements, from which the dovetail fastenings are determined. This at once fixes the dimensions of the dovetail in the wheel, and therefore of the rim surrounding it.

2. The general dimensions and contour of the wheel are then assumed with a view to anti-vibration characteristics. Reference is made to the records of wheels of similar bucket design and diameter. Two complete catalogs are kept, showing the vibration characteristics of all wheels so far tested. In one, these are listed according to dimensions, while the other one contains a list indexed according to the turbines for tracing the record of any particular turbine or wheel.

3. Calculation of stresses due to centrifugal force and a completion of the details of design are next in order.

4. The resulting design is reviewed from two standpoints. Stresses must be satisfactory, and the wheel must suit the space and clearance requirements for the turbine. Either one of these check inspections may serve to condemn the design and require a new start from the beginning.

5. When the foregoing have been satisfactorily concluded, a forging is selected and assigned. Each forging is examined for its physical properties by means of coupons, and for its uniformity by a magnetic survey of its entire structure, a complete record being kept of the forgings by serial numbers. All shop deviations are strictly included.

6. Standing vibration tests are then made for figuring the running resonant speed, and the wheel is tuned if necessary. One or two trials are usually sufficient to obtain the required vibration characteristics by tuning, though sometimes as many as five or six alterations are necessary. This necessitates a revision of the original drawing and corresponding alterations of all records and necessary calculations. In some instances the standing vibration test confirms predictions from catalog records to such an extent that the running test is omitted. Ordinarily, however, this test is required.

7. The seventh step consists of making complete running vibration tests in the wheel-testing machine. From 30 to 60 oscillograph films are taken, thoroughly indicating the behavior when running. If this should show undesirable characteristics, the wheel is then condemned and work begun again from the beginning. About 18,000 such records have been taken, of which one-third are preserved and available for quick reference. Films of special interest are added from time to time.

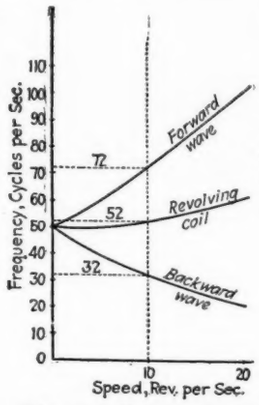


Fig. 10—Stationary wave increases frequency

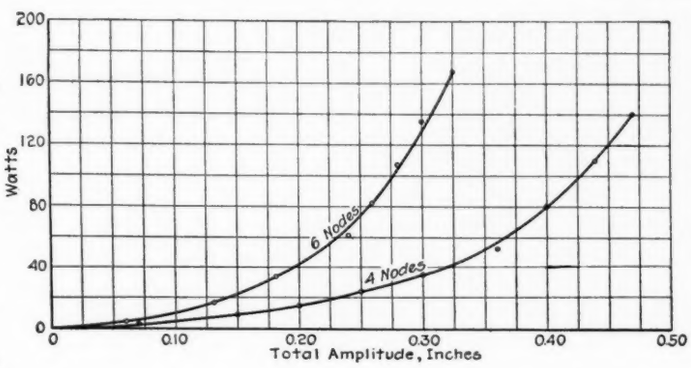


Fig. 11—How standing waves dissipate energy, as shown by electrical vibrator

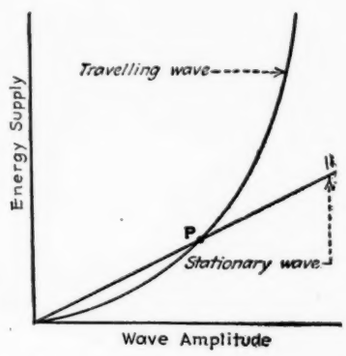


Fig. 12—Traveling waves start more easily

Appended Note on Wave Action[1]

The fluttering of flags, waving of trees, and even the unpleasant experiences of automobiling over a rough road are illustrations of vibration, endless varieties of which exist about us. As wind causes either slow waving or quick, violent fluttering of a flag, depending on whether it blows faintly or violently, so would stationary air tend to produce waving or fluttering in a thin rubber or steel disk, depending on whether it were revolved slowly or fast.

The thin disk, however, unlike a flag, is made of springy elastic material, and would flutter or vibrate even when not revolving provided it were struck with a hammer or subjected to a series of blows corresponding to any one of its natural periods of vibration. A circular saw, for example, of thin flat steel would tend to flutter, as shown at *A*, Fig. 13, if vibration were introduced by blows when standing still or by the action of air friction, if rotated rapidly.

A method of preventing vibration in circular saws was evolved many years ago. This consisted of two processes; first, producing uniform internal stresses by carefully testing and then expanding the metal in spots with a flat hammer as required, and secondly, a method of dishing or cupping as indicated at *B*. In the latter case a peen hammer is used to produce the cupped shape.

A saw four feet in diameter would require to be depressed about $\frac{1}{64}$ in. at the center. When properly adjusted,

[1] In the foregoing article an excellent description of wave action and conditions incident to propagation is included. Space limitations would not permit this to appear in full, and it is felt that a brief résumé would neither do the author justice nor convey the desired information. This note is therefore appended, with the idea of covering these phases of the subject briefly. Many of the examples given are cited by Mr. Campbell in the original article.

the disk would then run in a true plane as indicated at *C*. Sawmill operation with these large saws is thus made possible in spite of the natural tendency to vibrate or flutter. In the correction of a similar tendency in steam-turbine wheels other methods must be employed.

Backward traveling waves are produced in a flag by the air. If there were no wind, however, and the staff were moved rapidly forward, the waves would then travel from the staff to the far edge. Similar vibration in a rotating disk can easily be imagined as a backward traveling wave, resulting from the action of the atmosphere, and also the springy elastic material of the disk. If an uncorrected saw should revolve at 500 r.p.m., the

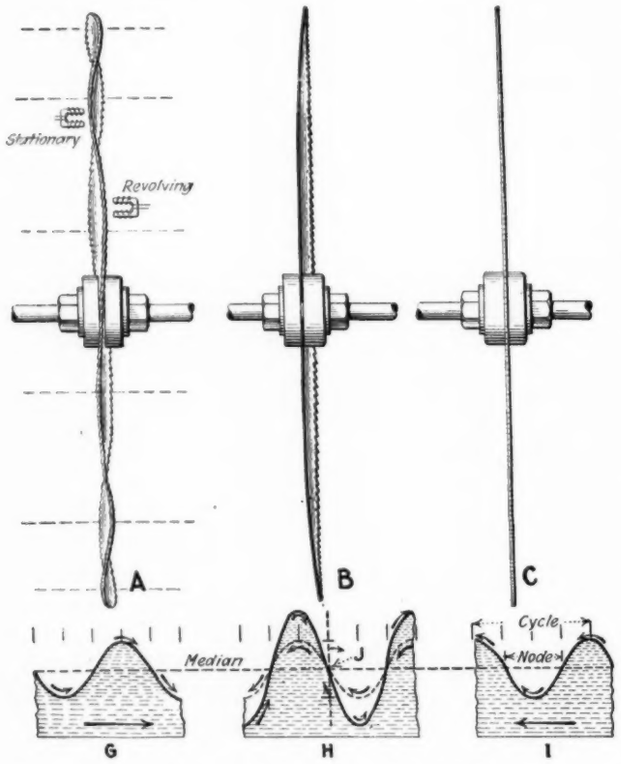


Fig. 13—Twelve-node wave at A *in saw eliminated at* C *by dishing as at* B. *Two surface traveling waves* G *and* I *meet and form stationary wave at* H

backward wave might rotate at 300 r.p.m. as measured from the disk. Although this would be termed a "backward" wave it would actually move ahead 500 — 300 = 200 r.p.m. if measured from a stationary point.

At *A*, Fig. 13, there are six bends or nodes to the left and six to the right, around the entire disk, which would be called 12-node vibration. If a stationary magnet were placed as shown, six of these left-hand bends would pass close to it in one revolution. Since the magnetism travels through the steel of the saw, the magnetic air gap would vary through six close gaps and six wide gaps in one revolution, representing twelve nodes or six complete cycles. If the magnet were connected electrically to an oscillograph in such a way that a curve could thereby be traced, showing the variation in distance between the saw and magnet, such a curve would show these high spots and wide gaps, as representing six complete cycles, for one revolution of the saw. If the backward wave travels 200 r.p.m. ahead with regard to stationary objects, the curve for one minute of operation would show 6 × 200 = 1,200 cycles,

In speaking of waves on turbine disks, however, this would be termed a 12-node wave, rather than 6 waves per revolution. It would also be a 300 r.p.m. backward traveling wave, since its speed is spoken of as if measured from the disk itself and not from a stationary point.

The term stationary wave does not mean one that does not rotate with respect to stationary objects. Rather, it refers to a wave that does not travel with respect to the disk. It is really made up of two traveling waves going in opposite directions.

Waves on water move away from the point wherein a stone is dropped; they are traveling waves. If two stones are dropped at a distance apart of, say, 10 ft., the traveling waves will pass through each other. The result would be a stationary wave, where the middle elevations remain stationary, but where crests lower into hollows and then rise to crests again without moving either toward the right or toward the left.

In Fig. 13, oppositely traveling waves *G* and *I* meet "head on," as at *H*. It will be seen that the crest heights are about doubled above the middle elevation or median line, and the hollows are also about doubled below. Points where this line intersects the traveling wave *G* move to the right, and similar ones in wave *I*, to the left.

The median point *J* of the combined wave *H*, however, is stationary. Such points occur at quarter-cycle intervals. In the next quarter-cycle of time, the maximum of wave *G* will be above and the maximum of wave *I* an equal distance below. Their average or effective value is therefore the point *J* on the median line. The wave crests actually will not travel sideways in this case, but rather will move up and down between the median points. When a saw or turbine disk is subjected to one or a series of blows at the same place, stationary waves are thus set up, which really consist of two opposite and equal traveling waves, with the disk edge representing the median line.

A standing wave shows the same sort of oscillogram on both magnets when the disk is not revolving. Suppose the moving magnet were attached so as to revolve with the disk. If rotated to 500 r.p.m. and the standing wave still persists unchanged, this magnet will show the same vibration as before.

The stationary coil, however, indicates differently. As the disk is first rotated slowly, the forward wave of the two that combine to produce a stationary one, will have its frequency increased. Suppose that when the disk had been vibrated, and the standing wave at any one point showed 300 cycles per minute, so that each complete cycle represents the forward wave traveling through two nodes, which is also one-sixth of the circumference. The entire six-cycle forward wave will then make $\frac{300}{6} = 50$ r.p.m., as will also the backward component wave. If the disk is given a forward rotation of 10 r.p.m., the forward wave will now register faster on the stationary coil, the speed then being 50 + 10 = 60 r.p.m. If the saw reaches 50 r.p.m., the 6-node wave will go forward at 100 r.p.m.

With the backward traveling component wave the reverse will hold. As measured from a stationary point its speed will become less as the saw rotates faster. If the disk goes 10 r.p.m., the backward wave will show 50 — 10 = 40 r.p.m. When the saw reaches 50 r.p.m., the backward wave will rotate at 50 — 50 = 0 r.p.m.; in other words, it will stand still with regard to the stationary coil. With a saw speed of 500 r.p.m. the backward wave would move ahead with regard to stationary objects at a speed of 500 — 50 = 450 r.p.m. In turbine wheels, backward traveling waves, close to turbine speeds, which nearly stand still regarding stationary objects have proved to be principally responsible for fatigue failures.

The question arises as to what would cause a faster traveling wave. Vibration depends to some extent on the elasticity of the disk. If it could be tempered harder and thus made stiffer, then shorter and quicker waves would result. Building the disk thicker with the same diameter would produce a stiffer structure, thus also giving a higher period of vibration. Another method of speeding up the vibration is to make the teeth of the saw thinner, or in other words, remove weight from the periphery. When vibrated mechanically, such as by a series of timed blows, variation in blow frequency will change that of the waves produced.

Stiffening can be produced by heating the hub of a disk to a higher temperature than the periphery. The internal strain may be thus greatly increased. Also, if the disk were rotated faster, centrifugal force would increase and tend to build up a greater internal strain. Faster vibration from this cause in turbine wheels is illustrated in the foregoing article.

Waves may be slowed up, on the contrary, by reversing any of the aforementioned conditions. Thus, taking metal

off the sides of a disk, or thinning it in places, tends to reduce stiffness or increase flexibility, and therefore to lower the frequency of vibration. This method is used in adjusting the critical speed of a turbine wheel or tuning when desired to remove the resonant speed from operating speed.

One more point should be considered. How does increasing the speed of vibration affect the number of nodes or high spots? Disks, if vibrated mechanically by a machine or series of timed blows, show first, the usual 4-node vibration at the lowest and critical speed. At a higher rate the 6-node critical appears, and at intervals the increased number of nodes corresponding to their resonant speeds. Critical speeds especially of four, six or eight nodes, should be an appreciable interval from the operating speed of a turbine, as the backward wave here does not revolve in space, and may be easily magnified by the effects of operation so as to cause undesirable results.

Spray Penetration

By H. F. Shepherd

No sooner do we evolve new knowledge of oil-engine working than some happily chosen word fastens itself upon us, seeming, as it does, to suggest a whole philosophy in a syllable or two. I wonder who invented or rather applied the word "penetration." Much theoretical guesswork has been written on the subject, and many useless experiments have been devised on its suggestion.

Dealing now exclusively with the multiple orifice spray and the Diesel-type combustion chamber, used together in one form or another in so many modern engines, should not the word orifice, of itself, suggest a limiting condition? We are obliged to get the fuel into the engine within a limited angular movement of the crank, or perhaps in a limited period of time would define the condition better. A five-hole tip has been adopted as a standard for a rather broad range of sizes and a 4,000-lb. spray pressure seems to be as good as any for full load. With this pressure and with five holes in the tip, the length of the injection period being fixed, there must be some variable to allow for engine capacity. This variable is merely and simply the size of the holes. Of course there will be some pressure drop during delivery. We can limit that or control it at will. We will assume it constant for the sake of convenience.

Let us consider a practical case. A commercial engine of record has a spray tip with five holes 0.020 in. diameter each. The area of each orifice is 0.000314 sq.in. This engine consumes forty pounds of fuel per hour when delivering 100 brake horsepower at 380 r.p.m. For purposes of simplicity of exposition it will be assumed that the oil weighs 7.7 lb. per gal. The consumption is then 1,201 cu.in. of oil per hour or say 20 cu.in. per min. This is divided into 190 charges of 0.105 cu.in. each, and each of the five holes discharges per injection 0.021 cu.in. of oil.

Oil of this gravity will stand at a head of 2.5 ft. per pound of pressure. Neglecting compression, the head on the orifice will then be 10,000 ft. for a 4,000-lb pressure. Now

$$V = \sqrt{2gh} = \sqrt{64.32 \times 10{,}000}, \text{ or } 802 \text{ cu.ft. per sec.}$$

As stated before, each hole discharges 0.021 cu.in. through an area of 0.000314 sq.in. at each injection. This will be, theoretically, a stream $.021 \div 000314 =$ 67 in. long. Our theoretical velocity is 9,600 in. per sec.; therefore the discharge at 4,000 lb. pressure should take place in $67 \div 9{,}600 = 0.007$ sec., if the orifice coefficient is 100 per cent. At 65 per cent, which is nearer truth, the discharge endures for $0.007 \div 0.65 = 0.01$ sec. This time is quite normal as most experimenters will agree. The same check applied to a number of cases, in my own experience as well as reported experiments, yielded approximately like results.

The next step in order was to investigate how thorough the penetration might be in engines, say of the Vickers type, once the required flow areas had been established. After pondering ways and means it occurred to me to try injection into water. Accordingly, the spray was set up in a glass jar, the walls of which were about as far from the points of issue of the tip as were the points of spray impact on the piston of the actual engine. The jar was filled with water. The spray was thus operated in an atmosphere far more dense than the cylinder air at the end of compression. The oil struck the glass walls, which appears to contradict statements of other engineers regarding the calculated energy of drops introduced into the combustion chamber. I think the reason is that because we

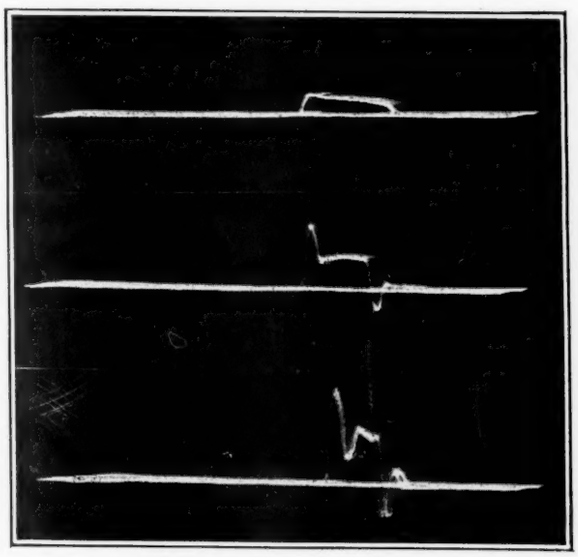


Fig. 1—Indicator diagram showing energy in an oil spray

are not introducing drops but a column of considerable penetrating power. The indications of atomization are largely friction effects on the surface for the first few inches of progress.

In order to get some idea of the energy remaining in the spray at a given distance from the orifice a single-orifice spray was rigged in such fashion that the jet issued upon a piston taken from a Hopkinson flashlight indicator. The motion of the piston was recorded by the regular Hopkinson mechanism which throws a beam of light on a photographic plate. The diagrams in Fig. 1 show the effect of the impact at 3 in. range. A minimum of 77 per cent of the energy was returned at 1,200 lb. spray pressure, while 89 per cent was recorded at 4,000 lb. These diagrams were taken in the atmosphere with a spray orifice 0.012 in. in diameter and 0.025 in. long. Similar runs on holes 0.019 in. in diameter oscillated the instrument so violently that no accurate data were possible with the spring employed.

If we do not really atomize the oil spray, what does happen? Further tests, spraying against a plate heated to a temperature approximating that of the piston

head when working at full load, told volumes. Had it been possible to heat the atmosphere above the plate to compression heat, the story would have been more complete. Most perfect and, to the eye, instant vaporization ensues upon the impact of the spray with the hot surface of the piston.

These remarks apply particularly to the so-called solid-injection Diesel engine in which the oil is sprayed through a short range toward and against the piston. Penetration must be limited somewhat by a proper selection of the number of holes and the spray pressure lest the energy of the jets cause them to penetrate the air screen washing the walls of the combustion chamber, thus allowing the oil to strike the cold surface. In the case of some engines the distance to the hot piston is so great that penetration must be encouraged by the use of a single orifice of considerable length.

Keeping Elevators in Safe Operating Condition

By Warren Hilleary*

There should be at least one inch, and preferably one foot, clearance between the bottom of the tension weights on the governor cable idler and the ground.

On any type of elevator it is desirable that there should be at least four feet of clearance between the head beam of the car and the overhead beams when the car is at the top landing, and preferably, six feet. The greater this distance the less liability of the car striking the overhead beams and the less severe is the twisting effect on the cables at the point where they enter the clevis or other fastening device on top of the car. On machines of the hand-rope or lever-control type the controlling device in the shaftway and the cables must be examined; the tension weights must be in suspension so that there is tension on the cables. If the tension weights are found to be at rest, due to the stretching of the cables, they should be immediately placed in tension.

The tension gear for the operating cable is frequently located on the overhead beams and consists of a lever with a weight attached to it, the lever resting horizontally. The weight must be secured in position by means of a setscrew, and the lever must be fitted with a U-clamp and chain, the latter secured to the overhead beams, so that, should the mounting for the lever break or the weight unship on the lever, the loose parts cannot fall down the shaftway. It frequently occurs that the turnbuckle, or the long-thread shackle, of one cable becomes loosened or one cable may stretch more than the other, thus making control uncertain and unsafe.

All movable parts of tension devices, located overhead, must be anchored with safety chains or iron cables, for not infrequently these movable parts work loose and fall down the shaftway. These parts are sometimes so improperly located that, should they get even slightly out of adjustment, the moving car or counterweight will strike them.

An unsafe condition exists where counterweights are found with slotted ends, for the reception of the counterweight frame rods, and where there are no separate tierods through holes in the counterweights.

The cleaning of elevator floors with water and washing powders is probably unavoidable, but the washing solution leaks through the openings in the floor and reaches the safety and controlling equipment, corroding them and in some instances making the safety equipment inoperative. Thus, it is seen that constant cleaning and oiling of all the equipment under the car is of great importance.

Mirrors and all other glassware should be eliminated from elevator cars, except that certificates of inspection, operators' licenses, annunciators and electric lights may have glass covers and shades. Electric light shades should be constructed of wire glass or else a substantial wire protection of small mesh should be suspended immediately under the shades.

Too little attention is paid to the fit between the shoes of both the counterweights and the car and their guides. These shoes should be kept in as near perfect order as possible, and when there is one-eighth of an inch wear in any direction, the shoes should be replaced with new ones unless they are adjustable. There have been instances where worn shoes permitted either the counterweights or the car to leave the guide rails, with disastrous results.

Some safety devices having the drum under the car, will be found also to have a roller situated immediately under the drum and held in position by bearings supported on four studs, the studs being equipped with springs, nuts and locknuts. It frequently happens that the nuts work loose, allowing the roller to move so far away from the drum that any considerable slack in the safety cable on the drum permits the cables to get out of the grooves, and then when an attempt is made to revolve the drum, when setting the safety, the displaced cable wedges between the drum and the car floor equipment, thus preventing the safety from setting. Since the nuts are not faced against any solid object, it is difficult to set the locknuts tight enough to keep them from loosening, and many operating engineers drill the studs both above and below the nuts and place a cotter pin through each hole. This is a desirable arrangement and insures the roller remaining in proper position and proper tension being kept on the springs.

The cable ends fastened to the car and the ends fastened to drum counterweights, except when swivel sockets are used, should be cut off at least once in two years and resocketed, to guard against breaking of the cables at the socket so far as is practicable. It is expected that the cables, under the conditions and at the points mentioned, may crystallize, although the remainder of the cable may be still usable and safe. It is desirable that the cut be made six inches above where the cable enters the babbitt, zinc or other fastening.

Care must be exercised to keep the nuts and locknuts on the bolts in the movable perforated sleeve of the controlling valve on horizontal hydraulic elevators, properly tightened. In a number of instances one or more nuts have worked loose and dropped down into the automatic valve, where they were caught between the edge of the moving valve and the port. This prevented the valve from closing, and as the car continued to move, the result was the breaking of the cast-iron yoke which formed a part of the automatic valve chamber head, and also a part of the automatic valve gear.

The method of lubricating the hoisting-cable sheave bearings and shafting by a single oiler or compression grease cup, located on the end of the shaft and communicating with an oilway through the center of the shaft and separate holes at right angles to this way, is not satisfactory because it does not insure lubrication of each sheave separately. It is advisable to have a separate compression grease cup in each sheave.

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A Notable Piece of Research

THAT all the precision of carefully calculated design sometimes fails to take into account lurking but dominant factors, is strikingly illustrated in the investigation into turbine-disk failures, as related in Mr. Campbell's paper, abstracted elsewhere in this issue. It was this factor of disk vibration, setting of a train of backward traveling waves equal in speed to the forward speed of the wheel, that proved to be chiefly responsible for the series of turbine failures which caused so much concern a few years ago. In a general way the tendency to vibration under certain conditions was recognized and mathematical analyses had been made by some turbine authorities, notably Stodola, but it was not until higher bucket speeds had been adopted and mechanical possibilities had been pushed to the limit to meet increased capacity that this type of vibration became manifest with disastrous results.

But calculations and theory proved totally inadequate to reveal the cause and indicate the remedy, and it remained for laboratory investigation to point the way. Fortunately, the great resources of the General Electric Research Department were at hand, and expense and effort were not spared in the work. The whole field of disk vibration was explored, and the contributing causes, such as feathering action of the steam and pulsating forces causing resonant responses in the wheel, were ascertained. The work did not stop here, however, for all wheels in service that were thought susceptible to this dangerous condition were tested, some being brought back to the works for laboratory tests, and a portable machine was designed to facilitate periodical testing of wheels in position.

It is regrettable that Mr. Campbell, who had such a large share in this investigation and who had thus gained such valuable experience in the turbine field, should have passed away within the last few days. His very remarkable paper, however, will remain as a monument to his work.

Testing Turbine Oils

ONE fact stands out as a result of research up to the present time in turbine-oil testing; the complicated methods suggested are in many instances far beyond the reasonable sphere of the average operating engineer's activities. Practical tests may easily be made to indicate the presence of an excess of acidity or animal fats, for example, but, on the other hand, processes characteristic of the chemical or research laboratory would be necessary in order to obtain a definite numeral representing the relative acidity or saponifying tendency. It seems as if the final result of standardization will be that testing processes will be practically unusable by the man in charge of an average plant.

Oil is widely recognized to be of complicated chemical structure. Difficulties in the way of accurate determinations are many, and methods thus far evolved are undoubtedly justified. It would seem that when oil tests have become satisfactorily standardized and many of the present difficulties overcome, some attempt should be made to provide more convenient testing methods, even if not so accurate.

The engineer of the small plant, however, is not entirely without means of determining relative oil conditions which usually bring success in operation. Sludging, change of color and the presence of foreign matter tell the story of unsatisfactory conditions. Experience can often dictate helpful changes in turbine-oil systems, such as lowering of operating temperatures and preventing contact with water. A few simple tests are available by which judgment may be assisted.

There is apparently much room for progress in the practical determination of the value of a lubricant in relation to any given set of conditions, so that trial and experiment may be obviated. A means of measuring the degree of favorable or unfavorable conditions in an oil system, therefore, would seem a necessary part of the process for determining the fitness of a given oil.

Benjamin G. Lamme

IN THE death of Benjamin G. Lamme the engineering profession has lost one of its ablest exponents. Entering the electrical profession almost thirty-five years ago, when this science was still in an embryo state, his versatile personality and genius soon began to impress themselves upon the industry and continued to be part and parcel of electrical development until his death. The leadership that he developed so early in his work he demonstrated throughout his career.

His contributions to the electrical art have been so varied that mention of the developments in which he has been prominently identified would appear like a history of the industry. There are certain milestones, however, that stand out and show his skill as an engineer in electrical development during the last thirty years. The design of the first generators used to develop power at Niagara falls on a large scale were his work. Previous to this the largest machines that had been built were only about one-tenth the size of the Niagara Falls units, yet many features introduced into these machines are practically standard today. In the design of engine-type generators his work reached its height of achievement in the Manhattan-type units installed in New York City to supply power to the elevated and subway railway systems. About this time the steam turbine began to make its appearance as a prime mover, and Mr. Lamme, foreseeing its possibilities, turned his attention to the development of high-speed turbo-alternators. The crowning achievement in this field of development was the

62,500-kva. unit recently installed in the Hudson Avenue Station of the Brooklyn Edison Company, this unit being of approximately eight times the rating of the Manhattan-type machines and occupying much less space.

In the railway field he has been associated with the development since its inception. Again in this branch of engineering his genius as a designer is demonstrated, in that today the modern railway motor bears a remarkable resemblance to that of thirty years ago. Working with Mr. Westinghouse, the development of the squirrel-cage induction motor was one of his greatest contributions to the industrial field.

Mr. Lamme, true to the highest ideals of his profession, always stood for progressiveness, always willingly obsoleting his best work to make way for something more promising. He spent a number of his best years in developing and bringing up to a high degree of perfection the direct-current engine-type generator only to turn around and make equally great effort in developing the twenty-five cycle rotary converter, and later the sixty-cycle rotary converter, which were destined to supplant to a large degree the engine-type direct-current machines. His work in obsoleting the engine-type alternator for the turbine-driven machine is another example of his progressiveness.

His many literary contributions on electrical engineering and his almost unequaled faculty for presenting involved subjects in a clear, concise and easily understood manner would have easily made him an outstanding figure in his chosen profession. Back of all his genius, engineering and scientific ability was a great human sympathy and understanding which endeared him to all who made his acquaintance.

Better Lighting in the Power Plant

IN ACCORDANCE with the popular movement for better lighting in homes, places of business and industrial plants it is befitting that more attention be given to better illumination in power plants. Few plants have been designed and put into operation that have a well-worked lighting system installed, notwithstanding the fact that the company may be conducting an extensive campaign for better lighting in almost every place but its own power plants. Good lighting, whether in the home or the business establishment, has proved its economic worth, and everyone familiar with the subject agrees as to the many benefits to be derived from proper illumination.

If power-plant operators are to be educated up to better standards of lighting in their homes and in places of business, it can hardly be expected that they can acclimate themselves very readily to a dark and dingy engine or boiler room. The fact that in industry faulty lighting has been responsible for about twenty per cent of the accidents and that a change from inadequate to proper illumination in manufacturing plants has resulted in increased production up to as high as twenty-five per cent, should be sufficient to demonstrate the importance of good lighting in the power plant. Although the output may not be affected by good lighting, it can have a marked effect on the morale of the attendants, which makes for high operating efficiency and reliability. Work in a power plant is more hazardous than that in many other industries, and every reasonable precaution should be taken to reduce the hazard to a minimum.

The possibilities of good lighting in power plants are not matters of conjecture. Proper illumination has been tried in some plants for years and its benefits demonstrated. In a number of the more modern plants fairly satisfactory lighting arrangements have been worked out for the turbine or engine room, but many boiler rooms and other parts of the plants are still lacking in illumination that would make them pleasing places in which to work.

It is apparently the consensus of opinion that since black coal is burned in the boiler room, everything else should be black. However, there are boiler rooms where a good part of the surfaces, especially those that reflect light, are painted white and in addition an adequate system of illumination installed; not only this, but these surfaces are kept white. Upon entering such a plant, one is at once impressed with the vast improvement in operating conditions over those where the older order of affairs is allowed to prevail and the lamps that are installed are not even kept clean.

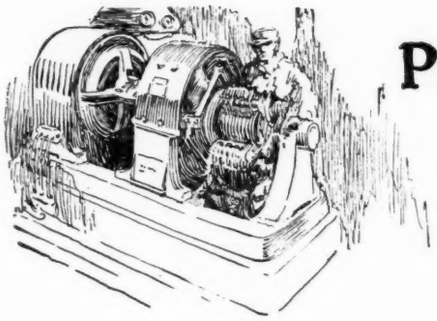
Many reasons have been advanced for the wide difference between the average operating efficiency of steam plants and the test efficiency, all of which no doubt are contributory, but improper illumination cannot be overlooked as an important factor. If those who are responsible for working conditions are not sufficiently interested to provide attractive surroundings, those who do the work can hardly be blamed for neglect and lack of interest in operating efficiency. It may be only a coincidence, but one of the best-illuminated plants in this country is also obtaining the best operating results, even though lighting is only one of the contributing factors.

Oil-Engine Operators Need An Association

ONE of *Power's* subscribers who is in charge of a power plant containing three Diesel engines has written to the editor that there is a need of some sort of association where Diesel engineers could exchange ideas and experiences. As he puts it, meetings of the several operating engineers' associations are devoted almost exclusively to the discussion of steam-engineering problems.

With the million and a half horsepower of oil engines in operation in this country there is indeed a vital need of some such organization. The one influence that might work against its successful functioning is the wide distribution of these engines. It would be unfeasible, if not impossible, to draw together any large percentage of the engineers, for this would entail too much train fare and time. The solution may lie in the formation of an association having regional or district meetings. Through these district meetings operators in a particular part of the country who necessarily are confronted with the same problems, could thrash out their difficulties.

A number of engineers have heretofore raised this issue, and it would be interesting, if indeed not helpful toward the organization of such an association, to learn what the readers of *Power* who are in charge of or concerned in the development of the oil engine, think of the idea.



Practical Ideas *from* Practical Men

Placing Operating Results on Blackboard Stimulates Interest Among Firemen

Some time ago we started a system in our plant with a view to working up competition among the firemen and thereby promoting better efficiency in the boiler room. A blackboard is mounted in a convenient place in the firing aisle, and each morning the results of the previous day's operation are put on the board, as shown in the table. The steam output on each shift is computed from the steam-flow charts, and the evaporation per pound of coal is determined by dividing this by the pounds of coal used per shift.

The man on the day shift has a little advantage over the others, as the load is heavier during the day than at other periods. In addition to three generating units with a total capacity of 1,025 kw., our plant equipment includes a large air compressor and two ice machines of 180 tons capacity. The boilers are Stirling type, stoker fired.

TABLE SHOWING RESULTS OBTAINED BY EACH FIREMAN

Date	Fireman No. 1 8 a.m. to 4 p.m.			Fireman No. 2 4 p.m. to 12 m.			Fireman No. 3 12 m. to 8 a.m.			24-Hour Daily Average		
Firemen	Actual Evaporation	Average CO_2	Stack Temperature	Actual Evaporation	Average CO_2	Stack Temperature	Actual Evaporation	Average CO_2	Stack Temperature	Actual Evaporation	Average CO_2	Stack Temperature
No. 1												
No. 2												
No. 3												
Monday	8.5	11.5	525	7.3	12.4	500	.7	11.2	475	7.6	11.7	500
Tuesday	8.5	11.7	510	7.4	13.3	495	7.4	13.5	485	7.7	12.8	496.6
Wednesday												
Thursday												
Friday												
Saturday												
Sunday												

The use of the blackboard has stimulated interest among the firemen, and the efficiency of our boiler plant has been considerably increased. The figures in the table showing the evaporation and the CO_2 are a good indication of the results we are getting.

Mounds, Ill. D. N. BAKER.

It Pays To Do Your Best

Wishing to have my pay raised, I approached the manager on the subject, and he informed me that he had never paid a fireman as much money as he was paying me and that he could replace me for twenty-five dollars a month less. This hurt my feelings somewhat, and I went back to the boiler room rather discouraged, yet planning how I could command more pay. My only hope was to improve in my ability, and then if I was refused an increase in pay, I could go elsewhere to get it.

At that time I was more or less indifferent with my work and was probably more of a coal heaver than a fireman. I realized that I had waited rather late in life to study and improve in my earning ability, as my age and responsibilities prevented me from going to an engineering school, and that if I was to make good, I would have to do my best with what knowledge and material I had at hand.

I first made a thorough inspection of the plant and made a list of things I needed to cut down the fuel bill. I took this list to the manager and explained the necessity of certain changes. He replied by saying that they changed firemen every year and each fireman had numerous things to be changed or installed, and while the things which I suggested might be used to a good advantage by me, the next man in my place would want something different. He did say, however, that if I could improve on any of the methods now in use, he would consider my results and be more willing to cooperate with me in any improvements. I was somewhat discouraged at first, but soon realized that he was right.

After spending some time reading and studying articles on boiler operation and analyzing the condition of my plant, I was ready to start my campaign for improvement.

I first got the bills of several years' fuel supply, which averaged $4,280. I then set out to reduce this by checking up on everything that was connected with the cost of operation. After determining the cost per day under present conditions, I wanted to see what could be done in the way of reducing the coal consumption. I started by paying particular attention to cleaning the flues and boiler shell, also stopping all leaks in the boiler setting. Wishing to know what improvements would be made in the draft by stopping the leaks in the setting, I made a draft gage by heating and bending a gage glass and connected it to the boiler breeching. After stopping all leaks, I found that with the same furnace conditions as formerly, the draft was practically 50 per cent better.

I also discovered that there was considerable variation in the draft on two of the boilers and found that this was due to the breechings from these two boilers entering the main flue directly opposite each other. In addition to this there were three right-angle bends in the breeching of one of the boilers. As it would cost a considerable sum to make the necessary alterations, it was out of the question to have it done then.

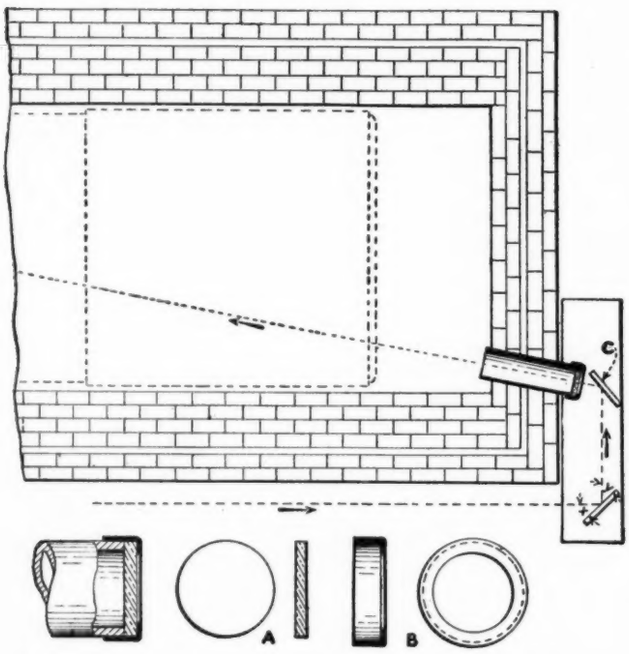
Nevertheless, I drew plans of things as they were and of the changes I considered necessary and put them on file until a more opportune time to approach the manager.

With the improvement that had already been made in the draft, I could carry a better fire with less smoke, so I turned my attention to improving my methods of firing. The first step in this direction was to provide a means of observing the condition of the fire at all times.

In order to do this, I cut a hole in the rear wall of the settings a few inches below the bottom of the boiler shell. In this hole I placed a 4-in. pipe 22 in. long and cemented around it with fireclay. The end of the pipe was allowed to project outside of the wall about an inch, and on this end I fitted a circular glass *A* and a tin cover *B*, as shown in the illustration. This made a removable window that could be easily cleaned and replaced and yet make an airtight joint.

I was now able to study the action of the burning fuel, and after each firing when I was quite sure that the fire was burning brightly, I went around to the rear to see what was taking place, making such changes in the damper setting or admitting more air above the fire as appeared necessary.

After I had experimented for some time with different methods of firing and had observed the conditions of my fires by walking around to the rear of the boiler, I



Periscope arrangement permits observation of furnace conditions

devised a periscope arrangement whereby I could see the conditions of the fire while in front of the boiler.

The periscope was made of two mirrors about six inches square placed at right angles to each other and spaced so that one would be directly in front of the pipe while the other extended a few inches beyond the side wall of the setting as shown.

The board on which the mirrors are placed is suspended by two wire slings about two feet in length. This permits swinging the shelf out of the way if necessary to view the fire directly through the pipe. The mirrors were fastened to the board by nailing a strip of wood on each side. Care should be taken when locating the mirrors on the board, as much depends on getting these properly set. Probably the simplest way to do this is to lay out the lines representing the lines of vision and then locate the mirrors so that the angle x equals the angle y.

The periscope proved to be a valuable aid in regulating the depth of the fire and the proper amount of draft on the furnace, as I could observe the furnace condition at all times without opening the furnace door.

My knowledge of firing led me to keep the furnace full of flame with a small tint of smoke in it, which was clearly seen through the glass, the tint of smoke indicating that I was not admitting too much air. Also, I could tell exactly when to fire and how much draft was needed. I could use a certain coal or mixtures of coals of different grades and get equal results. This was important as we often had to change coals for various reasons. In addition I could tell when there was a clinker or a portion of the fire through which air was not passing; I could also govern the amount of coal I fired at one time so as not to make much smoke. A brief outline of what I learned by the glass to be the best methods of firing and banking follows:

When starting a fire, I use the best coal first. This forms a good bed on which small-sized coal can be thrown without falling through the grates. By doing this until the fuel bed is well coked, I am able to get good results and burn up a lot of fine coal that otherwise could not be used. After the fire is well under way, I fire every few minutes with a small shovelful of coal, which I spread the full length of the grates and about one-third the width of the furnace. By firing in this way the gases given off by the fresh coal are consumed by the clear burning part of the fire.

I have been able to save considerable fuel by simply watching my fires near quitting time and having them thin and level. When it is time to bank the fires I push back the live coals to the bridge wall, allowing the ash and clinkers to remain on the grates. I then close all dampers and drafts, for there is practically no volatile left to be driven off. In the morning the ashes and clinkers are removed from the front portion of the grate and the banks evenly spread over the whole surface. By banking the fire in this manner I can save 100 to 150 lb. of coal each night and have cleaner flues in the morning than when green coal is used in the bank as was formerly the practice.

After the plant had been operating for some time under these improved conditions and considerable saving had been made in our fuel bill, I was called to the office to have my previous suggestions reconsidered. I went with drawings, figures and suggestions, practically all of which were approved. In addition I was given a 10 per cent increase in salary and a certain percentage of the savings.

Wanting to further improve my boiler operation, I purchased a CO_2 instrument to serve as an additional check on my method of firing. When using the instrument, I always observed the condition of the fire and the flame through the periscope, and in this way I was able to improve my general boiler operation to a still greater extent.

What I have stated is only an outline of the benefits that I have accomplished from my experiments and efforts to improve the efficiency of my boiler plant, but it has given me the confidence and experience that will enable me to take on a larger plant on similar conditions where larger savings are possible. It has also earned for my employer and myself a nice bonus, as the fuel bill for last season was less than $1,780 and there are prospects of this being reduced still further. In concluding I will add that what I have accomplished is within the reach of the average fireman if he is willing to reach for it.

C. RYE.

Winnipeg, Man., Canada.

Comments from Readers

"The First Steamboat"

I read, in the April 15 issue, the newspaper article entitled "The First Steamboat." In matters of this kind power men do not rely very much upon the daily press for historical records on things mechanical, and while this article may be described as fairly accurate as a whole, some details are misleading. In decrying the pioneer work of Fulton, the American, the following statement is made: "The previous year (1789) William Symington had a boat on the River Carron in Scotland, equipped with engines built by the Carron Iron Works Company." This statement is somewhat misleading, as William Symington, beyond making the engines for the first successful steamboat, had nothing to do with the matter, and to assert that the Carron company built the engines is a serious injustice to this clever engineer. Also, the River Carron, wherever that may be, was not in the picture.

The first successful steamboat was built by a Patrick Miller, who was a pioneer shipbuilder, the engines, as mentioned, being built to Mr. Miller's order by Symington in Edinburgh, Scotland. The boat was removed to Dalswinton Lake, and it was on Oct. 14, 1788, that the first successful trial was run and was heralded as a new and mighty power, and was no doubt, as claimed, the forerunner of steam navigation. On board this boat was a passenger named Alexander Nasmyth, father of James Nasmyth, of steam hammer fame, and in his biography the matter is fully dealt with, and a sketch of the boat by Alexander Nasmyth is given, while the original engines are preserved in the South Kensington Museum, London, as the engines of the first steamboat, and may be seen by anyone interested.

It is quite true that long before this various attempts had been made for the mechanical propulsion of ships, but none appears to have been successful, although some credit is certainly due to several others besides Patrick Miller, as he frankly admitted that Symington was the first to suggest steam engines as a method of propulsion.

F. P. TERRY.

Belfast, Ireland.

Effect of Excess Air on Flue Temperatures and on Efficiency

The curves given in A. Kristian Bak's article on the "Effect of Excess Air on Flue Temperatures and on Efficiency" in the April 22 issue, will be of great interest to plant engineers.

As stated, the curves apply only to the particular boiler and setting on which the tests were made: they also hold good only for a particular coal, for any considerable variation in the fuel composition will upset the CO_2 readings. When working in power stations, I have often thought that such curves correlating boiler efficiency, CO_2 per cent, stack temperature and excess air would be of great assistance to the engineer in charge. As the coal analysis usually varies but little from month to month, one accurate test should establish the relations for a particular boiler, and the only additional equipment to the usual standard would be the thermocouple in the stack. Any marked divergence from the standard curves would immediately indicate something wrong with the instruments, with the coal, the draft, or the firing, or that the boiler should come off the line for cleaning. The curves also show what saving can be effected by air preheating, especially with such boilers as the Scotch-marine type, in which the efficiencies are 10 to 15 per cent below that of the modern power-plant boiler.

Readers will probably have observed that Figs. 3 and 5 are almost exact mirror reflections of Figs. 2 and 4; the latter curves, in fact, would have been quite sufficient, as examination will show that the excess air ratio n follows almost exactly the law, $n = \frac{18}{CO_2}$, which shows that with perfect combustion the boiler could not carry more than 18 per cent CO_2. Prof. R. H. Smith, in his book "Boilers, Economizers and Superheaters," after examining a large number of British bituminous coals gives the rule $n = \frac{17.5}{CO_2}$. However, the figure to suit any particular coal may be arrived at quite simply and with sufficient accuracy in the following manner: Assuming a British coal of composition $C = 80$ per cent, Hydrogen 5.15 per cent, Oxygen 5.6 per cent, and neglecting sulphur, ash and moisture, the hydrogen available for heating $\left(H - \frac{0}{8}\right)$ $= 4.45$ per cent and the ratio $\frac{4.45}{80} = 0.0556$. Multiplying this by the ratio of the heating values of hydrogen[1] and carbon, $\left(\frac{52{,}200}{14{,}400} = 3.625\right)$, we get 0.22.

If coal were all carbon and just enough air supplied to give complete combustion, we should get $n = \frac{21}{CO_2}$

The CO_2 is increased in the ratio 1:1.22 because the hydrogen forms water which does not appear in the gas analysis, and as we have increased carbon (on the fuel) in this ratio, we must increase the CO_2 in the same ratio.

For this particular coal then—

$$n = \frac{21}{1.22 \times CO_2} = \frac{17.3}{CO_2}$$

Mr. Bak made no actual measurements of the excess air supplied, but an analysis of the coal must have been made to obtain the excess-air ratio, and if this had been given it would have been interesting to compare the figure obtained from the curves with the empirical rule herein given, which may prove of use to readers of *Power*.

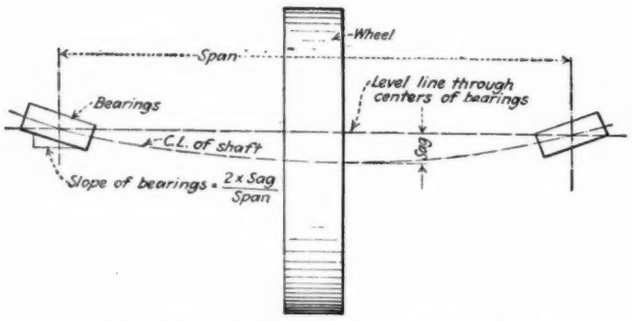
B. MURDELL THORNTON.

Newcastle-on-Tyne, England.

[1] Lower heating valve.

Why Should the Bearing Not Be Set Level?

Referring to Pierre Willet's article in the May 27 issue on leveling engine bearings, the sag of the engine shaft from the weight of flywheel and generator armature is well recognized, but the expedient of tipping the engine frame or, perhaps more likely, planning the main bearing seat and cap to this slope is less usual, as the babbitt bearings are usually scraped in to allow for this or the bearing shells have enough clearance to swing and adapt themselves. I know of one large tandem-compound Corliss, 1,500 hp., on which this was not done and the main and outboard bearings ran hot until the chief engineer, an old marine man, had the bottom liners taken out and the two outer of the three bearing strips planed off so that the liner could tip on the center one and adapt itself to the slope of the shaft.



Illustrates shaft deflection (exaggerated)

Of two engines for which I have the complete data at hand, I have figured the shaft deflection and stress due to the dead weight of flywheel, etc. The first of these was a 500-hp. simple belted Corliss with rather short, large shaft and belt wheel with comparatively thin rim. This showed a calculated deflection of only 0.0015 in. and a stress of 1,250 lb. per sq.in. The other was a 400-kw. cross-compound high-speed Corliss, direct connected to a three-phase 60-cycle 2,300-volt generator and, to allow of belting to an exciter from the engine shaft and to shift the alternator stator to one side to work on armature coils and revolving field, had a rather long shaft. This showed a deflection of 0.029 in. with a maximum stress of 3,700 lb. per sq.in. Since the shaft was approximately 10 ft. long, this could give an average slope on each side of 0.006 in. per foot, but as the curve of deflection is approximately a parabola, the slope at the ends will be double this or 0.012 in. per foot, an amount that could readily be detected by a level sensitive to a tissue paper or 0.0015 to 0.002 in. under one end.

From the theory of beams, shafts made of the same material and stressed to the same degree will have deflection directly proportional to the square of the length and inversely proportional to the diameter, so that it may be seen that if a shaft of, say, 13 in. diameter and 86 in. between bearings will carry a load of 20,000 lb. with a deflection of 0.0015 in. and a stress of 1,250 lb. per sq.in.; yet if the same diameter shaft be lengthened to 172 in. and the load reduced to 10,000 lb., the stress will still be 1,250 lb. per sq.in., but the deflection will now be 0.006 in. and, if it can be conceived that the shaft should be made 258 in. long and the load reduced to 6,667 lb., the stress would still be 1,250 lb. per sq.in. but the deflection would be 0.035 in. Or, expressed in terms of common experience, the shaft, while amply strong, becomes too whippy or springy.

It is probable that in slower-speed speed engines at any rate the shaft deflection continues as the shaft revolves, so that the shaft is bent back and forth at each revolution. This is the standard method of testing materials for fatigue or the crystallization point, and it has been found that as long as the greater stress does not exceed a fraction of the elastic strength of the material, which is usually greater than the stress used in designing engine shafts, this bending back and forth for a very large number of times, 10,000,000 to 100,000,000, will have no bad effects on the material.

I agree with Mr. Willet that the most satisfactory way of setting up an engine is to have the leveled parts level and then, if the bearings need shimming or scraping in, conduct this as a separate operation.

New Haven, Conn. H. D. FISHER.

Connecting Up Power-Factor Meters

Commenting on the article in May 20 issue, "Connecting Up Power-Factor Meters," it appears that a little more detail and explanation would be beneficial, as the information given applies specifically to the three-phase meter, apparently of the moving-vane type, although a resistor should be shown in the center potential leg to make it exactly balanced. Two resistors are used with the two-coil dynamometer type meter, and with two-phase meters of both types.

The interchanging of the two ungrounded leads in the two-phase meter will throw the deflection off 90 deg. in addition to causing incorrect phase rotation in the meter. The two-phase meter, however, is practically obsolete, as one or two single-phase meters are preferable in this measurement.

These instructions also do not apply to the three-phase single-current and potential-coil meters, which are in reality only single-phase meters with a split-phase resistor-reactor but with the pointer advanced 30 deg. to read three-phase power factor.

The last paragraph is the test for correct phase sequence and not for connections. For example, there are 11 incorrect connections and 1 correct one for a three-phase meter, these incorrect connections being caused by reversed current transformer, current transformer in wrong phase and wrong phase sequence.

The correct way to check three-phase connections is as follows:

1. If the meter is of the limited scale type, figure out the power factor from the voltmeter, ammeter and wattmeter readings, or the kilowatt and reactive kilowatt-ampere readings and see that this value falls within the scale range.

2. Check mechanically, if at all possible, and see that the current transformer is connected to the same leg that feeds the common voltage.

3. If deflection is in the lower part of the scale in 360-deg. type or pointer against the bumpers in limited-scale type, then reverse current-transformer leads.

4. Test for phase rotation by partly short-circuiting the current coil and noting that the pointer moves toward the lag direction, as stated in the previous article.

These instructions do not apply to the two-wattmeter type power-factor indicator nor the wattmeter-reactive component type indicators of the pantograph or the ball types. VICTOR H. TODD.

Summit, N. J.

Notes on Making Screwed Pipe Joints

The reading of the article entitled "Notes on Making Screwed Pipe Joints," by E. Andrews, in the June 3 issue, suggested to me that the rehearsal of some of my experience with this work may be helpful to those not especially familiar with pipe fitting, but who are called upon from time to time to do some replacement work and possibly small portions of new installation.

Expert information is not claimed for what is to follow, but its use has proved satisfactory in actual practice, and it is written here for what it may be worth to others.

Mr. Andrews' statement, "After threading a pipe, it should be possible to screw the fitting on by hand only about two threads," I believe from personal observation of joints thus treated, is not good advice. This method will make a tight joint on small pipe, but on 1-in. pipe and larger the tightness will be only temporary, especially on lines where considerable vibration or excessive expansion and contraction conditions are present.

The table given herewith for the number of threads a fitting should be screwed on by hand followed by a wrench are not theoretically correct, but I have found them satisfactory in actual practice:

SIZE OF PIPE AND NUMBER OF TURNS FITTING SHOULD BE SCREWED ON

Pipe Size	Turns by Hand	Turns with Wrench
1 in.	4½	3½
2 in.	4½	4
3 in.	5	4½
4 in.	6	4½
5 in.	6½	5
6 in.	7	5

The increase in pipe size by one-half inch from 1- to 4-in. is not given, for the turns as indicated will work out satisfactorily. The table applies more especially to low- and medium-pressure work.

When two threads are all a fitting can be screwed on by hand, forcing with a wrench will in many cases produce a leaky joint from the start, for the following reasons:

When the average quality of cast-iron fitting is used, frequently a fitting will be found cracked when the pressure is applied; if not at once, soon afterward, due to expansion in high-temperature lines. If malleable fittings are used, they will stretch and leaks will develop. I have proved both of these statements.

Threading machines usually have marks or lines on the stock and also on the dies to indicate the proper setting. When these lines coincide, the dies are supposed to be in the position to insure a standard thread for the pipe size indicated, with one cutting. This setting will work all right on standard pipe with a new thin model die; however, I prefer to make two cuts to produce the finished thread, even with good sharp dies and particularly so with dies that are dull. Liberal use of lard oil is also essential when cutting threads to insure a good thread and prolong the life of the dies.

Given sound fittings, clean-cut threads and the joint properly made up, no "dope" will be required to produce tight work; however, a little graphite and oil or graphite pipe-joint compound brushed over the threads will facilitate making up the joint, and whenever it may be necessary to dismantle, the joints can be broken more easily.

When existing pipe lines need repairs or changes and no flanges or unions are near, the portion to be removed may be cut out and with the use of a ratchet stock the remaining ends threaded in place and flanges or unions used for connecting up the new work.

When this work is being done, make sure that the portion of the line to remain in place is securely braced during the cutting and threading process. If this is not done, leaks are likely to develop at the joints in the old line.

The same precaution should be taken when making repairs to lines that have been in use for a considerable length of time.

A. K. VRADENBURGH.

New York City.

Fire and Water Tubes Used with Return-Tubular Boilers

I was interested in the article in the Feb. 19 issue describing the experiments carried out by Mr. Lippincott, of the Keller Boiler Co., on the circulation of water in the horizontal-return-tubular boiler. If his theory is true, there is no advantage in spacing the tubes farther apart in the center in this class of boilers. In my opinion they do not steam any better than the boilers built thirty years ago, where all the tubes were an equal distance apart. The size of the tubes is an important detail in fire-tube boilers. Personally, I would not buy boilers with 4-in. tubes. A boiler with 3-in. tubes will beat them every time, if properly cleaned.

I have had considerable experience with three return-tubular boilers, two of 1,500 sq.ft. and one of 1,250 sq.ft. of heating surface. One of the 1,500-sq.ft. boilers has seventy 4-in. tubes, the other one hundred 3½-in. tubes. The 1,250-sq.ft. boiler has one hundred and six 3-in. tubes and is much the best steamer of the three. Now I believe the chief reason the boiler with the larger tubes does not steam well is because the gases are not broken up into a small enough stream for a good heat transfer. Also, it seems to me there is too much propaganda about riveted joints exposed to the furnace heat. I know a return-tubular boiler in actual service for thirty years, that has never had a leak in the seams. If the boiler is kept clean and free from mud and scale and the feed water is reasonably clean, I fail to see how the joints will be affected by the heat. The same applies to the tubes of a water-tube boiler.

Now here's a question I should like someone to answer through the columns of *Power*: Does the water in the upper drum or drums of the water-tube boiler increase in temperature after leaving the water tubes until it passes into the tubes again? I don't see how it can.

Again, suppose we take the return-tubular boiler and circulate the water over the fire tubes at the same rate that it passes through the drum of the water-tube boiler. Would not this increase its steaming from 5 to 10 per cent? Water tubes under a fire-tube boiler will no doubt help circulation, but here we rob Peter to pay Paul. I am of the opinion that the steaming capacity of a return-tubular boiler can be greatly improved by getting a rapid and positive circulation through the shell of the boiler. I should prefer a boiler that will make steam as fast as the water-tube boiler and have the holding up quality of the return-tubular boiler. This I believe can be done.

I expect to show in *Power* a design of boiler embodying some of these features as soon as patent pending is granted. Many believe the steam boiler has reached its highest efficiency. Perhaps it has, but I still think there is considerable room for improvement particularly in the return-tubular type.

W. W. GILLETTE.

Gloversville, N. Y.

QUESTIONS AND ANSWERS

Conducted by Franklin VanWinkle

Vertical Circulation Space Between Fire Tubes

For what reason is a vertical row of tubes left out in the center of a horizontal return-tubular boiler? *G. R. L.*

The purpose of omitting a central row of tubes is to provide a central vertical circulation space over the hottest part of the fire to induce a concourse of steam bubbles. Strong descending currents nearer the shell supply the water necessary to continue the vertical circulation. If the channel through which steam bubbles rise is too narrow, the circulation is arrested and the disengagement of steam is less uniform, commonly resulting in agitation of the water to such an extent that it is productive of perceptible vibration of the boiler and connections.

Weight of Coal in Storage Pile

How can an estimate be made of the number of tons of coal in a coal storage pile? *W. H. M.*

Storage piles of commercial sizes of anthracite vary in weight from 58 lb. per cu.ft. in the larger sizes to about 54 lb. per cu.ft. of buckwheat. Piles of free-burning bituminous coals weigh about 56 lb. per cu.ft., and storage piles of the lighter Middle West coals weigh about 49 lb. per cu.ft. Variation in weight of different grades of coal is not due solely to the specific gravity of the solid coal. The weight of a given bulk depends largely on the quantity of surface moisture, the proportions of coarse and fine sizes, and the amount of shaking or settling as the coal is delivered or as stored. As ordinarily handled and piled, it is customary to allow about 36 cu.ft. of bulk per ton (2,000 lb.) of anthracite and 40 cu.ft. per ton of bituminous coal.

Hunting of Shaft Governor

What causes a shaft-governed engine to speed up and hunt? *W. L. C.*

Racing and hunting may be due to friction of the governor parts. When this is the cause, the weights will stick in their inner position until the speed developed is so high as to throw them out with a noise; or when the engine is above speed they will stick until the speed is reduced enough for the springs to draw them back again. Hunting or racing would also result if the weight force and spring force are unbalanced, and rapidly alternate. If the hunting persists after the governor parts and connections are perfectly cleaned and lubricated, the remedy is to give less tension on the springs to decrease their sensitiveness and change the weights to get the correct speed. When hunting is caused by spring tension alone, the changes in speed will be rapid and even.

Exhaust Lead of Slide Valve

What is exhaust lead on a slide-valve engine, and how is it measured? *H. A.*

When the crank is on the dead center, the distance a valve is open is called lead. Although the term is more commonly confined to the distance a valve opens a cylinder port of an engine, for the admission of supply steam when the piston is exactly at the end of its stroke within the cylinder, the distance that the exhaust edge of a slide valve has uncovered the exhaust edge of the port when the piston is at the end of the stroke, is known as the exhaust lead. To find the exhaust lead of a D slide valve for either end of the cylinder, place the engine at dead center on the end for which the lead is to be measured and make a mark on the valve seat at the end of the valve. Then remove the valve from its seat and measure the distance from the same end of the valve to the exhaust edge of the valve. The difference between this measurement and the distance from the mark previously made on the valve seat to the exhaust edge of the cylinder port will be the amount of exhaust lead.

Loss of Economy from Generation and Use of Wet Steam

When steam at the pressure of 100 lb. gage contains 4 per cent moisture, what per cent less heat is required for generation of the steam from a feed-water temperature of 180 deg. F., and how much less efficient is the wet steam for use in an engine? *W. L. C.*

The total heat in a pound of dry saturated steam at the pressure of 100 lb. gage, or 115 lb. per sq.in. absolute, is 1,188.8 B.t.u. above 32 deg. F., of which 309 B.t.u. is the heat of the liquid and 879.8 B.t.u. is the latent heat of evaporation. When 4 per cent of the wet steam is moisture, the total heat per pound would be the heat of the liquid plus 100 — 4 = 96 per cent of the latent heat of evaporation, or 309 + 96 per cent of 879.8 = 1,153.6 B.t.u., which is 1,188.8 — 1,153.6 = 35.2 B.t.u. less than required for generation of a pound of dry saturated steam. Since the generation of a pound of dry saturated steam at the given pressure, 115 lb. absolute, from feed water at the temperature of 180 deg. F. would require 1,188.8 — (180 — 32) = 1,040.8 B.t.u., the generation of steam at the same pressure but containing 4 per cent moisture would require 35.2 × 100 ÷ 1,040.8 = 3.47, or about 3½ per cent less heat per pound.

In reciprocating engines no reasonable variation of moisture content at the throttle has appreciable influence on the dry-steam consumption. The water remains inert, neither helping nor hindering. Therefore steam containing 4 per cent of moisture, as supplied to the cylinder of an engine, would be 4 per cent less efficient

than the same weight of dry saturated steam. Since the heat required and consequently the cost of generating a pound of the wet steam is 3½ per cent less than for a pound of dry saturated steam, and the value of the wet steam used in the engine is 100 — 4 = 96 per cent as great, the cost of generating and using the wet steam would be $\frac{100-3.5}{96}$ as much, that is about ½ of 1 per cent more, than if dry saturated steam were generated in the boiler and used in the engine. This, however, is without taking into account somewhat greater losses from condensation in conveying wet steam in place of dry saturated steam from the boiler to the engine cylinder, or crediting the heat recovered in water returned by a separator in the steam supply line.

Interlocks on Elevators

On elevators what are the interlocks and for what are they used? *W. H.*

Interlocks are mechanical devices that require that the elevator door be closed before the car can be started in either direction. They require that the car be at or within a predetermined distance above or below the landing before the door can be opened. There are also electrical devices, sometimes referred to as interlocks, which are intended to have the same effect. It is important that there be a means through which the car operator can render the locking device inoperative in case of emergency, and the device should be so arranged that evidence of the operator's or other attendant's act in this respect will be easily noticeable. A desirable arrangement is a mechanical interlock on the shaft door and, in addition, a car door that closes with this door. The car should be inoperative until both the car door and the enclosure door are closed and latched, and the opening of either door should be impossible until the car is brought to rest within two inches above or below the landing.

Engine-Cylinder Lubricator

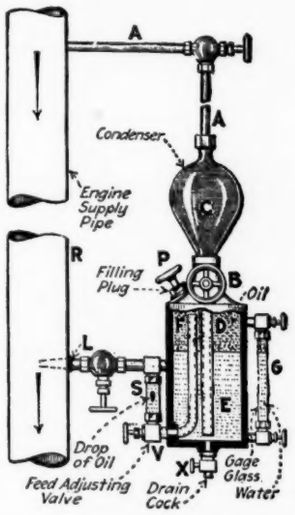
What is the method of operation of a hydrostatic engine cylinder lubricator? *L. N. C.*

The general arrangement of a double-connected hydrostatic sight-feed lubricator is shown in the illustration, in which the body of the lubricator is partly cut away so that its internal construction and operation may be understood. The body of the lubricator contains cylinder oil *D* and water *E*. The water is supplied from condensation of steam admitted from the engine steam supply pipe *R* through the connection *AA* and gathered in the condensing chamber *C*. When the valve *B* is open, the condensate in *C* gravitates through a vertical pipe to the bottom of the lubricator where the hydrostatic pressure of the water in *C* or connection *A*, aided by the steam pressure in *R*, exerts an upward pressure on the oil. The level of the water *E* is shown by the gage glass *G*.

The total upward pressure exerted by the water *E*, forces the oil out through the bent pipe *F*, open at its upper end near the top of the oil chamber, and thence is discharged through the regulating valve *V* upward through water in the sight-feed glass *S* and delivery pipe *L* into the main steam pipe *R*. The delivery pipe *L* should be extended for some distance into the main steam pipe, as indicated by the dotted lines, and usually is provided with perforations or some form of nozzle for breaking up or atomizing the oil as it is delivered. When the valve *V* is closed and valve of *L* is opened, the sight-feed glass *S* becomes filled with water formed by condensation of steam entering the connection *L*.

To fill the lubricator with oil, first close valves *B* and *V* and then open the drain cock *X* and remove the filling plug *P*. When all water *E* is drained out, close the drain cock *X*, pour in the oil at *P* and replace the filling plug.

For proper operation of the lubricator the chamber *C* must be full of water or the oil will be broken up by admission of steam to the water space *E*. In case *B* has been left open or sufficient time has not been allowed for condensate to fill *C*, the lubricator should be completely emptied and permitted to cool with the valves *B* and *V* closed. Then, after refilling, replace plug *P* and, with *S* filled with water, open *B* and adjust *V* to the desired rate of feed indicated by drops of oil rising in *S*. The lubricator should be started and stopped with the engine. Just after the lubricator has been refilled, it is difficult to adjust a constant feed, especially at a slow rate, because the feed is affected by the changes in viscosity of the oil due to changes in temperature.



Sight-feed cylinder lubricator

Advantages of Four-Valve Engines

Why should better economy be expected of a four-valve engine than a single-valve engine? *R. N. C.*

Four-valve engines can be designed and constructed with shorter steam passages and less percentage of cylinder clearance than necessary for single-valve engines, sharper cutoff is obtainable, and the valves can be adjusted and controlled independently of each other so as to obtain better steam distribution, especially for variable loads. There are also the additional advantages that the admission steam is not cooled from so much area of the admission valves coming in contact with the exhaust, and there is less trouble from water in the cylinder as the exhaust valves may be so located that the condensed steam drains through them.

[Correspondents sending us inquiries, should sign their communications with full names and post office addresses. This is necessary to guarantee the good faith of the communications and for the inquiries to receive attention.—Editor.]

Here and There in the Power Plant

Sidelights on things generally used but less generally understood

"Lifting" an Elephant

AT A RECENT fair the crowd looked on with open mouths while the professional strong man "lifted" an elephant. He was not very large as elephants go, weighing possibly two tons. But that, in the opinion of the crowd, was quite enough for any man to handle.

This stunt of lifting an elephant may seem far removed from the field of power production. In reality, however, it is an excellent example of an almost universal occurrence in the mechanical world. The push of the connecting rod on the crank of a steam engine is not the same as that of the steam on the piston. Each arm of a double-chain sling carries a tension greater than half the actual weight supported.

The engineer who understands the elephant-lifting trick can solve such problems with ease. Moreover, he has

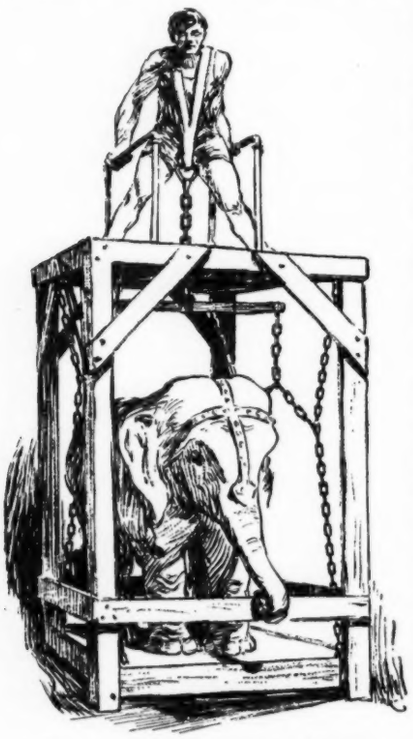


Fig. 1—How much is he lifting?

a stunt that may find direct application in the power plant in certain types of erecting jobs.

The sketch (Fig. 1) gives the general scheme of the trick. The man stands on a four-legged table or platform. Beneath is a small elephant standing on a square platform, the four corners of which are suspended by nearly vertical chains from the corresponding corners of the upper platform. Evidently, the elephant could not fall even if the man went away. The centers of the two chains on one side are connected by a horizontal chain. Attached to the center of this, in turn, is a short length of chain running vertically to one end of a "whiffletree." The other end of the whiffletree is connected to the chains on the other side in exactly the same manner.

The "lifting" is done through a vertical chain which passes from the center of the whiffletree up through a hole in the overhead platform to a broad strap around the man's shoulders. Incidentally his actual lifting power is increased by railings placed at such a height that the load can be divided between the arms and legs.

When the man lifts, the small cross chains are pulled up in the middle. This in turn pulls the centers of the vertical chains out of line, thus raising the lower platform slightly. The whole contraption is mechanically equivalent to a pair of toggle joints in series.

Turning to Fig. 2, it is of interest to trace out the forces in such an arrangement. Reasonable proportions have been assumed. Mechanically, the question is: For the proportions and angles shown what force at the middle of the whiffletree is necessary to sustain 4,000 lb. on the platform?

Fig. 2 shows the network on one side only of the frame, the 2,000 lb. weight representing the load carried by this side. There is then a straight downward pull *a* (due to gravity) of 1,000 lb. on each of the lower eyebolts.

The first step is to resolve the forces acting at this point. The known force of 1,000 lb. is laid off to scale vertically downward from the eye. The force in the chain necessarily acts along its length. For balance there must be one other force acting horizontally to the left. So the directions of all three forces and the size of one of them are known. The size of the other two forces *b* and *c* is found by drawing the force triangle, all sides of which are parallel to the known directions of the forces, with the arrows pointing the same way. Moreover, the arrows must all run around the triangle in the same sense.

By scaling, *c* is found to be 1,040 lb. No attention need be paid to *b*. Evidently, the force acting downward along the chain from the next junction will also be *c* and the directions of the other two forces will be known. So the triangle is drawn as before and *e* (380 lb.) is transferred to the next junction with the direction reversed. From the symmetry of the figure the same force *e* is acting in the right branch.

Completing this triangle gives a vertical pull *f* of 230 lb. With another 230 lb. on the other end of the whiffletree, the total weight actually supported by the man is only 460 lb. instead of 4,000 lb. Evidently, the

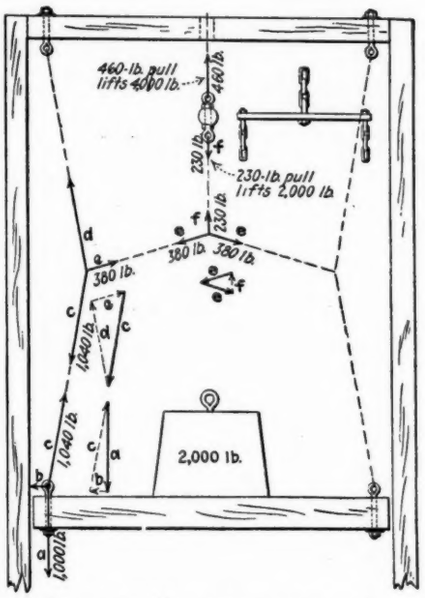


Fig. 2—Problem solved by drawing force triangles for each intersection

force required will grow steadily larger as the lift is increased.

Thus any man, however weak, could lift the elephant a certain distance, while no man could lift it very far.

If the problem were analyzed in terms of work alone, it would be found that the work accomplished was no greater than that done by the man. Work equals force times distance. Where the force varies, work equals the average force times the distance. Neglecting friction, which would be small in this case, the average force exerted by the man multiplied by the distance he raises the whiffletree must be equal to the weight of the elephant multiplied by the rise of the suspended platform.

It would then be possible to figure the average force exerted by the man if the relative distances moved could be found by measurement. For example, if the man must raise the whiffletree ten inches to lift the elephant one inch, the average force he exerts over this range is $4{,}000 \div 10 = 400$ lb.

These two methods of figuring mechanisms—the resolving of forces and the use of the law that the work taken out equals that put in (minus losses)—have countless engineering applications. Facility in handling these methods is of practical value to the operating engineer.

Pulverized-Coal Installations in France

Two notable French pulverized-coal installations are described in the leading article of the May 17 issue of *Le Génie Civil*. One of these is in the central station of Vitry, in the department of the Seine, and the other in the Gennevilliers station, whose original installation was described in the Aug. 1, 1922, issue of *Power*. As will be seen from the following brief description, much of the equipment is of American design.

Fig. 1 shows a cross-section of one of the Ladd-Belleville boilers for the Vitry station. Some of the principal dimensions are shown on the drawing, and additional data are given in the table. Steam is withdrawn from the rear upper drum, which is slightly higher than the others to insure a lower water level and less entrainment of water in the steam. The baffling arrangement shown, with seven passes including superheater and economizer, insures a high gas velocity and hence a good rate of heat transfer.

The Elesco superheater used has a heating surface of 5,160 sq.ft. Diamond soot blowers are employed. The lower part of the wall at the bottom of the boiler is composed of removable panels which permit the removal of any refuse that may collect there.

The Lopulco system of pulverized-coal burning is used, comprising the burners and the two water screens, the lower one of which cools the ash dust before it falls into the pit, the other protecting the refractories of the back wall. A Dieterlein steel-tube economizer is used, as modified by the Ateliers de Saint Denis. To avoid corrosion, the water is degassed before entering the economizer and is given a sufficient velocity in the economizer to produce turbulent flow. It is claimed that this entrains the air bubbles that would otherwise adhere to the walls and accentuate the corrosion. The feed water is heated to about 195 deg. F. by the exhaust of steam-driven auxiliaries and by steam bled from the turbines.

The economizer is composed of 20 elements, separately demountable (10 on each side) connected in parallel between their headers. The interior diameter of the tubes is 1.2 in. and the exterior diameter 1.5 in. Each element consists of two series of tubes, so that the feed water traverses 40 sections.

Fig. 2 shows the general layout of the pulverized-coal system at Gennevilliers, which is substantially the same as that at Vitry. The coal-preparation apparatus is placed in the boiler room.

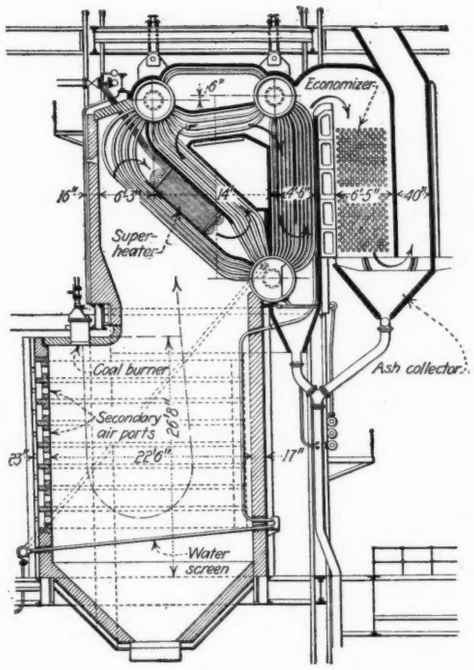


Fig. 1—Cross-section of boiler at Vitry

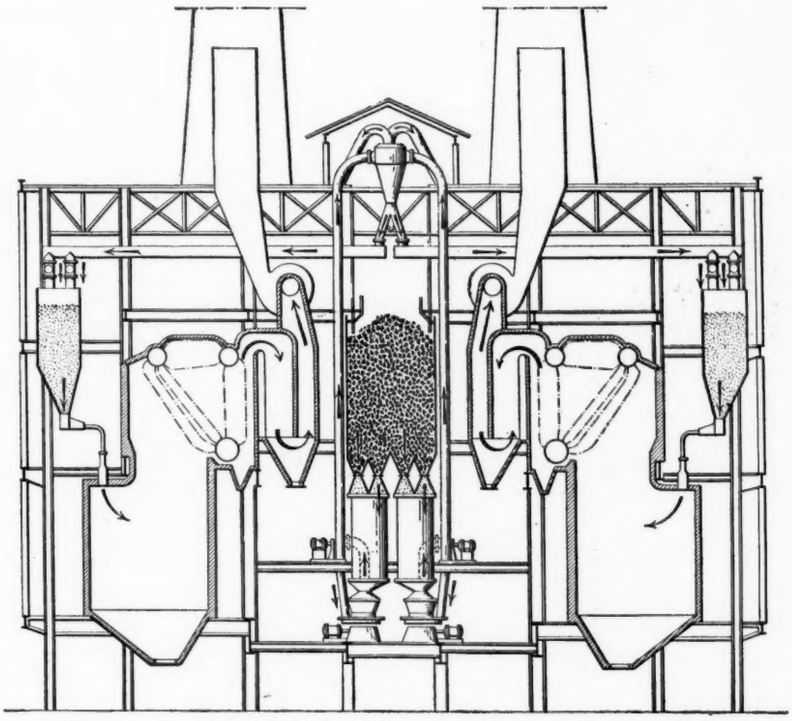


Fig. 2—Powdered-fuel installation in Gennevilliers station

DATA ON BOILERS AT VITRY

Boiler heating surface, sq.ft.	19,720
Superheating surface, sq.ft.	5,160
Economizer surface, sq.ft.	14,000
Steam pressure, lb. per sq.in.	256
Steam temperature, deg. F.	750
Length of drums, ft.	28
Diameter lower drum, in.	55
Diameter upper drums, in.	47
Diameter of tubes closest to fire, in., inside	2.9
Diameter of tubes closest to fire, in., outside	3.2

Coal falls from the storage bins through driers to Raymond pulverizers. From these the pulverized coal is lifted to a cyclone separator under the roof, whence it is delivered to the pulverized-coal bunkers of the different boilers. Arrangements are made for feeding the burners of one boiler from a neighboring pulverizer if necessary.

Coal is admitted to the burners through six feeders. It is first picked up by the feeder screw and then by a current of primary air (about 10 per cent of the total), delivered by fans at a pressure of 16 in. of water. Secondary air is drawn in through the openings in the furnace by the induced draft. The installations are being made by the Société anonyme des Foyers automatique.

Fatigue of Metals Research

One of the most important projects of engineering research now under way in this country is the investigation of the fatigue of metals conducted by the Engineering Experiment Station of the University of Illinois (Urbana) in cooperation with the National Research Council, the Engineering Foundation, the General Electric Co., the Allis-Chalmers Manufacturing Co., the Copper and Brass Research Association, and the Western Electric Co. The investigation was organized in 1919. The first report of the work appeared in Bulletin 124 of the Engineering Experiment Station of the University of Illinois. Bulletin 136 contains a second report. Abstracts of these bulletins appeared in *Power*[1] soon after their publication.

Bulletin 142, written by Profs. H. F. Moore and T. M. Jasper, and recently issued by the Experiment Station, gives the latest findings of this investigation.

The most important discovery of the earlier work was that a given specimen of any metal had what might be called a fatigue limit for a given kind of repeated stress. Take the case of a short round rod subjected alternately to tension and compression of equal

[1]Issues of Dec. 13, 1921, and July 17, 1923.

amount by a machine constructed to alternate these stresses thousands and even millions of times automatically. In each case there appears to be a certain stress that can be repeated indefinitely without the specimen failing. A slight increase in the stress causes the specimen to fail after a few thousand reversals. In determining this fatigue limit, specimens have been carried through a complete cycle of tension and compression as many as one hundred million times.

There are many varieties of repeated stress. The type just mentioned is found in the piston rod of the steam engine. A long rotating shaft loaded in the middle with a heavy wheel undergoes a reversing bending test as the shaft is rotated. There are many other combinations. In this investigation machines have been constructed to reproduce all the more common types of repeated stress as many times as desired.

The latest bulletin gives additional evidence of the reality of the endurance limit, at least for wrought ferrous metals. Specimens that had previously withstood millions of cycles of stress without failure were retested and found not only not to have been damaged by the previous stressing, but actually to have been strengthened. This strengthening effect was most marked for those steels that are susceptible of improvement in static strength by cold working.

The conclusion may be drawn that repeated stress at or below the original endurance limit of a wrought ferrous metal raises the endurance limit for that metal. A few cycles of repeated stress above the original endurance limit of a wrought ferrous metal lower the endurance limit for that metal. A wrought ferrous metal injured by such over-stress may have its strength partly, but rarely wholly, restored by polishing its surface, or by repeated stress below the endurance limit. The specimens tested seem to show up better under reversed bending stresses than under alternating compression and tension, the average endurance limit of wrought ferrous metals being only about 64 per cent as much for the tension and compression test as for the bending test.

The direction of the stress in relation to the grain of the metal was found to have an effect upon the endurance limit as well as upon the static ultimate tensile strength.

The bulletin calls attention to the fact that the old theory of "crystallization" as an explanation of fatigue of metals has been entirely abandoned. Metals are always crystalline. The present general belief seems to be that fatigue failures start at some minute region of highly localized stress and that its beginning is a tearing apart of minute pieces of metal. Fatigue failure proceeds by the spreading of these fissures.

Repeated stresses, according to this bulletin, produce in a metal both strengthening and destructive effects. The strengthening effects include the improvement of bearings between adjacent crystalline grains or other small particles of metal. The destructive effects consist in the actual tearing apart of particles in the metal, with the consequent formation of minute cracks, which have a tendency to spread. There is presented the further conception that for wrought ferrous metals the strengthening effects overbalance the destructive effects below a fairly well defined fatigue limit, but that above this limiting stress the destructive effects predominate, and failure occurs if the stress be repeated a sufficient number of times. Space is lacking to call attention to many other valuable conclusions contained in this 88-page bulletin.

Water Power in the Canada Pulp and Paper Industry*

As it takes practically one hundred horsepower to make one ton of paper per day, the indispensability of an abundant supply of low-priced power is apparent. In any industry the relative necessity of obtaining cheap and adequate power may be gaged by the amount required per dollar value of product, and, with the possible exception of certain electrochemical and metallurgical processes, the requirements for the manufacture of pulp and paper rank among the highest. It is therefore little surprising that over 90 per cent of the motive power in this industry is derived from the energy of waterfalls.

While the average consumption of power for the conversion of pulp wood into paper is 2,400 hp. per ton per day, one large Canadian mill uses 1,750 hp. for each ton of mechanical pulp produced, 1,600 hp.-hr. of which is for the actual grinding alone. The production of sulphite pulp for mixing with the ground wood pulp requires 209 hp. per ton of daily output (in other large mills as high as 720 hp. was used per ton of sulphite pulp produced), while the conversion of the pulp to newsprint required 288 hp. for the same unit of output.

The continuous operation of mills in this industry, usually 24 hours a day, lends itself to the securing of a very low cost per unit of power used, as the main cost item is the interest on the capital expended in the hydraulic development, and this remains constant whether the plant operates ten hours a day or twenty-four. The development of the electric steam generator has become an added factor in reducing this unit cost, in that any surplus or off-peak power that may be available, can be utilized for producing steam for pulp cooking, drying, heating and similar uses.

At the present time the hydraulic power utilized in the pulp and paper industry totals to 726,375 hp., and the rapidly growing change to electric drive is shown by the fact that 438,708 hp., or over 60 per cent of this total, is converted into electricity before use. Of this latter total 210,755 hp. is purchased from central electric stations. The last completed census conducted by the Dominion Bureau of Statistics, that for the year 1922, shows a steam-power installation in pulp and paper mills of only 60,764 hp. or less than 10 per cent of the total installation.

Quebec has 56 mills powered by 368,352 hp. of hydraulic or hydro-electric energy. Of this, 151,792 hp. is direct-connected to pulp and paper machines, 85,440 is connected to generators and 131,120 hp. represents power purchased from central stations. Of this purchased power the nine mills that generate no hydraulic power purchase 88,385 hp., the rest 42,735 hp. being additional power purchased by generating mills. The total daily producing capacity of these mills is some 3,000 ton of mechanical pulp, 1,500 ton of chemical pulp, 1,400 ton of newsprint and 740 ton of other kinds of paper.

Ontario has 46 mills requiring a total of 271,174 hp.; of this amount 174,189 hp., made up of 89,066 hp. direct connected and 85,123 hp. connected to generators, is installed in the plants of the pulp and paper organizations, while 96,985 hp. is purchased from central electric stations. The total daily production of the mills in this province aggregates 2,200 ton of mechanical pulp, 1,800 ton of chemical pulp, 1,900 ton of newsprint and 735 ton of other kinds of paper.

British Columbia, with only five mills, has a total installation of 55,140 hp., of which 26,790 hp. is direct-connected to pulp and paper machines and 28,350 hp. is converted to electricity before use. None of these mills finds it necessary to supplement its own installation by purchased power. The two large mills at Ocean Falls and Powell River have installations of 26,850 hp. and 24,000 hp. respectively. The combined daily production of the mills in this province reaches some 390 ton of mechanical, 430 ton of chemical pulp, 445 ton of newsprint and 30 ton of other paper.

New Brunswick has only four mills operated by water power, with a total installation of 13,728 hp. and a daily producing capacity of 30 ton of mechanical, 300 ton of chemical pulp and 50 ton newsprint paper.

Nova Scotia has ten mills operated by water power. These mills are all of moderate size and have a total installation of 17,331 hp. Their daily producing capacity is some 200 ton of mechanical pulp and 50 ton of newsprint.

*Extract from bulletin issued by the Department of the Interior, Canada, Dominion Water Power Branch.

HYDRAULIC POWER IN CANADIAN PULP AND PAPER MILLS

Province	No. of Mills	Turbine Installation in the Industry: Direct Drive, Hp.	Turbine Installation in the Industry: Hydro-Electric Drive, Hp.	Turbine Installation in the Industry: Total, Hp.	Purchased Hydro-Electric Power, Hp.	Total Hydro-Electric, Hp.	Total From All Sources, Hp.
British Columbia	5	26,790	28,350	55,140	.....	28,350	55,140
Ontario	46	89,066	85,123	174,189	96,985	182,108	271,174
Quebec	56	151,792	85,440	237,232	131,120	216,560	368,352
New Brunswick	4	2,668	11,060	13,728	650	11,710	14,378
Nova Scotia	10	17,251	80	17,331	.....	80	17,331
Total	121	287,567	210,053	497,620	228,755	438,808	726,375

Recent Publications

The Supervision and Maintenance of Steam Raising Plant. By C. A. Suckan. Published by The Van Nostrand Co., New York City. Cloth; 7¼x9⅝ in. 342 pages. 250 illustrations. Price, $8.

Although referring principally to British and European practice, a large portion of the information contained in the volume is so general in its character that it can be applied in practically any power plant. The book has been written with a view to assisting power-plant owners, managers and engineers in the more efficient operation of their plants under existing conditions. An endeavor has been made to present the information in the simplest possible form, and the discussion of the theoretical side has been reduced to a minimum.

The volume has been divided into two parts. The first part deals with supervision of the plant, while the second treats on the repairing and general overhauling of the component parts. The volume has been written from a practical operating and maintenance point of view and covers the subject very thoroughly as will be apparent from the list of chapters that follows: Part I—Organization; Combustion of Fuel, Method of Firing, Regulation of Draft, Superheaters, Economizers, Pumps, Injectors and Meter, Handling of Fuel, Handling of Ashes, Feed-Water Plant, Pipe System; Routine of Boiler-House Staff, Office Staff, Testing. Part II—Internal Inspection, External Inspection; Boiler Brickwork; Laying Up, Auxiliary Appliances, Auxiliary Plant Brickwork; Workshop Organization, Feed-Water Plant, Pipe Lines and Structural Repairs.

Developments in Power Station Design. By Edwin Austin. Published by Van Nostrand Co., 8 Warren St., New York City, 1924. Cloth, 7½x11 inches; 271 pages; 239 illustrations. Price, $9.

The author's position on the editorial staff of *The Engineer* (London), one of the world's outstanding engineering publications, gives promise of practical value to the contents. This promise is fulfilled. The book is the outcome of a series of articles published in *The Engineer* during 1921 and 1922, representing the latest information obtainable in the field at that time. While power-plant practice is changing with extreme rapidity, the time elapsing between the publication of these articles in the magazine and their appearance in book form is so small that this book may be said to represent the latest British practice. The treatment throughout is descriptive rather than mathematical. After a preliminary chapter on electrical supply, in which Great Britain's superpower problem is outlined, there is a discussion of pulverized-coal equipment. This is based largely on American practice, although British practice predominates throughout the rest of the book. For example, the following chapter on oil fuel deals almost entirely with British equipment. The subjects of low-temperature carbonization, waste-heat boilers and air heaters are covered in brief chapters. The short chapter on boilers is of interest because it describes types that are practically unknown in American stationary practice. Mechanical stokers and coal and ash handling are very briefly handled. A description of a commercial installation using a "thermo" compressor adds interest to the chapter on evaporators. Fuller treatment is given to turbo-generators and condensers, particularly the latter. The chapter on turbo-generators is devoted largely to the modifications of design made necessary by high steam temperatures. That on condensing plants deals with a subject to which British engineers, perhaps largely due to their naval interests, have given a great deal of attention. Their design in this field has taken an individual trend, so that British condensing apparatus is immediately distinguishable from American by its general appearance. Perhaps both are equally good, but American designers could doubtless gain valuable information by studying the British designs, and vice versa. A chapter on high-pressure steam plants deals mainly with the design details of a plant operating on 350 lb. at 700 deg. Chapters on instruments, switch gear and other electrical equipment complete this very interesting book.

Practical Mathematical Analysis. By H. Von Sanden, Professor of Mathematics at the University of Clausthal. Translated by H. Levy, Professor of Mathematics, Imperial College of Science and Technology, London. Published by E. P. Dutton and Co., New York City. Cloth, 6x9 in.; 195 pages. Price, $4.50.

This volume is correctly described by its title. It is practical in the sense that the writer has constantly and clearly in mind the goal of the engineer—the answer. The other half of the title shows the limitations, the reader's limitations rather than those of the book. The reader must have a substantial mathematical background, as much as might reasonably be expected of a technical graduate. Granted such a background, certain types of readers will find this book wonderfully helpful. The technical specialist, who must analyze experimental data, construct empirical equations, compute engineering tables, etc., will here learn how to plan and conduct his computations to get results of suitable accuracy in the minimum of time. The author, while able and willing to use all the traditional methods of the mathematician, does not stop there, but explains and encourages the use of such engineering tools as the slide rule, the calculating machine and the planimeter. Other subjects covered are numerical and graphical integration, various methods (mechanical and otherwise) of solving equations, measurements of area, interpolation of arbitrary functions, etc. The book should be in the library of every research worker.

Mechanical Engineers' Handbook. Lionel S. Marks, Editor-in-Chief. Published by McGraw-Hill Book Co., Inc., 370 Seventh Avenue, New York City; 6-8 Bouverie St., E. C. 4, London. Cloth; 4½x7 in.; 1,986 pages. Price, $6.

To those familiar with the "Mechanical Engineers' Handbook" Lionel S. Marks, Editor-in-Chief, the mere announcement of the appearance of the second edition, representing engineering practice and theory as it stands in the beginning of 1924, will tell the story perhaps better than a voluminous description of the contents.

The first edition reached a total of 65,000 copies, and such typographical errors as it may have contained are, it is believed, practically eliminated in the second. The book has been increased by 150 pages, with revision of the original text. This includes condensation and elimination of considerable portions, which have been more than balanced by the new material added.

Drying and lubrication are among the new topics added, while hydraulics, heat, iron and steel, non-ferrous metals and alloys, bearings, steam boilers, internal-combustion engines, aëronautics, and air compressors have undergone a great amount of change. The power test codes and similar material in most cases are as of Jan. 1, 1924. In some instances the text has been submitted to other specialists for criticism and suggestions. All but one of the previous contributors have been retained, while eight new ones appear.

The operating engineer unfamiliar with the advantages of this handbook will be interested to know that such information as how to line up and level a lineshaft, determining if a stack is vertical, water rates for steam turbines, descriptions of bleeder turbines, types of steam-engine valve gears, safe loads on wire ropes, lubrication for various types of machines, storage and safety of coal, and many other useful facts are available.

In addition to much important practical information the book itself is essentially an engineering work. Up-to-date theory is plainly put forth, and many reference tables are of great convenience. As a compendium for engineering knowledge, which the power-plant engineer must have from time to time, this volume is commended.

To those who desire an education in engineering, it must be remarked that this handbook may, with some application, be made the equivalent of a college course. It is perhaps not realized that such elementary subjects as arithmetic, how to handle the slide rule, geometry, trigonometry, and others more complicated, are put forward in a remarkably brief and easily understood manner. With a minimum amount of personal application and perhaps at times a little outside help, the man interested in self-education will find this book unusually well suited for conveniently grasping the entire mechanical engineering field, as well as such subjects as building construction, surveying and concreting.

Wabash River Plant Went into Service July 4

The first two units of the Wabash River power station of the Indiana Electric Corp., a division of the Central Indiana Power Co., went into service on July 4 and on July 8 began delivering industrial power to Indianapolis and 127 other central Indiana cities and towns. These units provide 55,000 hp. and will soon be followed by another unit of the same size and later by others until the full station capacity of 135,000 hp. is reached.

This great electric power station is installed directly in the coal fields. The plant eventually will cost $12,000,000.

Exposition of Inventions Will Be Held

The American Institute of the City of New York will hold an exposition of inventions in the Engineering Societies Building, New York City, Dec. 8-13. There will be exhibits from the leading American industries showing the developments of various machines, utilities and processing methods. In all fields the ingenuity of the inventor and the part he has played in the progress of America will be emphasized.

Arrangements for the display of working models or actual devices can be made through a Committee of the American Institute at 47 West 34th St., New York City.

Canadian Stationary Engineers Meet

The Canadian Association of Stationary Engineers held its annual convention at St. Thomas, Ont., from June 23 to 26. The convention was the most progressive, harmonious and successful ever held by this organization. The ritual was done away with, leaving more time for the discussion of education and employment service. The association was placed on a Dominion wide basis, similar to the N.A.S.E. by establishing Provincial branches of the Grand Lodge, C.A.S.E., with almost complete autonomy to the provincial branch of the Grand Lodge.

The Western Association of Mechanical Electric (operating) Engineers, Edmonton, Alberta, decided to affiliate with the Association and the Grand Lodge has approved. They now become the Province of Alberta Branch of G. L., C.A.S E., with headquarters at Edmonton, Alberta. Similar or kindred associations in other provinces have also applied for affiliation and action will be taken upon these applications at the next convention.

Famous Engineer Dies at Age of 60

Benjamin G. Lamme, chief engineer of the Westinghouse Electric & Mfg. Co., and a pioneer in the electric field, died at East Liberty, Pa., on July 8, after a lingering illness.

Mr. Lamme, who had more than 150 inventions in his name, was born on a farm near Springfield, Ohio, on Jan. 12, 1864. He was graduated from Ohio State University in mechanical engineering in 1888. There he excelled in mathematics, being a master of high-range multiplication tables and differential calculus and discovering many "short cuts" in mental calculation. He became interested in electricity and entered the Westinghouse employ at $30 a month in 1889 and became chief engineer in 1903.

Benjamin G. Lamme

His most spectacular designing achievements were: The generating equipment for the World's Fair in Chicago in 1893; the 5,000 hp. generators which first harnessed Niagara Falls; the single-phase alternating-current generating and motor equipment for the first big railway electrification on the New York, New Haven & Hartford; the design of the most successful synchronous converter ever used; and the single reduction-gear street-car motor which, designed in 1890, is the type still used on street railway systems.

He received the highest honors from the American Institute of Electrical Engineers, being awarded the Edison Medal in 1919; elected as one of the two members of that body on the Navy Consulting Board during the war, and made chairman of the Invention Committee of that board. He also received recognition from other educational institutions and scientific organizations.

Mr. Lamme made many contributions to the electrical science which have found world-wide recognition, and his research and development work have made its impress upon the application of electricity to industry in every country in the world. A paper, "Induction Motor," published about 23 years ago, is used in many schools and included in the textbooks of the Naval Academy.

Edison and Steinmetz were his close friends as well as professional rivals. The Ohio State University last year cited him as "the greatest living mathematician," an honor previously bestowed only twice, upon Edison and Steinmetz.

Mr. Lamme, who never married, lived with two sisters, one of whom was for many years chief designer of direct-current motors for the Westinghouse interests and occupied a desk beside that of her brother in the drafting office. He is survived by a brother, William F. Lamme, of San Rafael, Calif., and four sisters.

Large Generator Ordered by Edison Company

The Southern California Edison Co. has recently placed with the Westinghouse Electric & Manufacturing Co., an order for a 28,000-kva., horizontal waterwheel generator which will be installed in the company's Big Creek No. 1 plant. The machine is so designed that at a speed of 300 r.p.m. it delivers current at 11,000 volts 50 cycles, and at a speed of 360 r.p.m., current is de livered at 12,000 volts 60 cycles. The generator is complete with a direct-connected exciter.

Consumers Are Thought To Be Using Stored Coal

While the impression prevails among governmental agencies in Washington that decrease in consumption of coal has not been proportionate to the reduced production of the bituminous mines in recent weeks, the accuracy of this opinion cannot be established until there is a more thorough examination of statistics of consumption and until other data in relation thereto are secured.

In its report, dated July 5, the Survey comments that while there is ample evidence that consumption has declined during the first half of the year, it appears obvious that production declined at a more rapid rate and that therefore there has been an "appreciable" draft on the 62,000,000 tons of soft coal which was held by consumers on Jan. 1, the date of the latest census of stocks.

Great Lakes Electric Power Survey Published

Gives Capacity of Present Stations and Estimates Energy Requirements for 1950

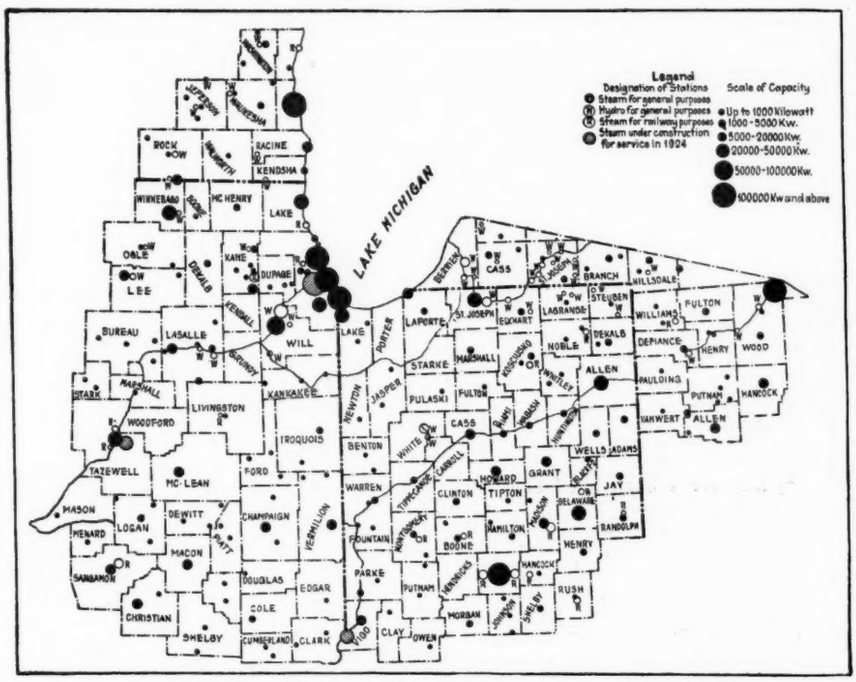
THE National Electric Light Association, realizing its opportunity for service in the evident interest displayed by the public in the rapid growth of electric systems and the increasing demand for power, has started a study of existing conditions and by estimates of increases in population and needs of sections of the country, has outlined a plan for development, which it will publish as an "Electric Power Survey." The first report is on Area A of the Great Lakes Division which takes in parts of four states.

One of the most interesting chapters of this report deals with estimated conditions in 1950. It states:

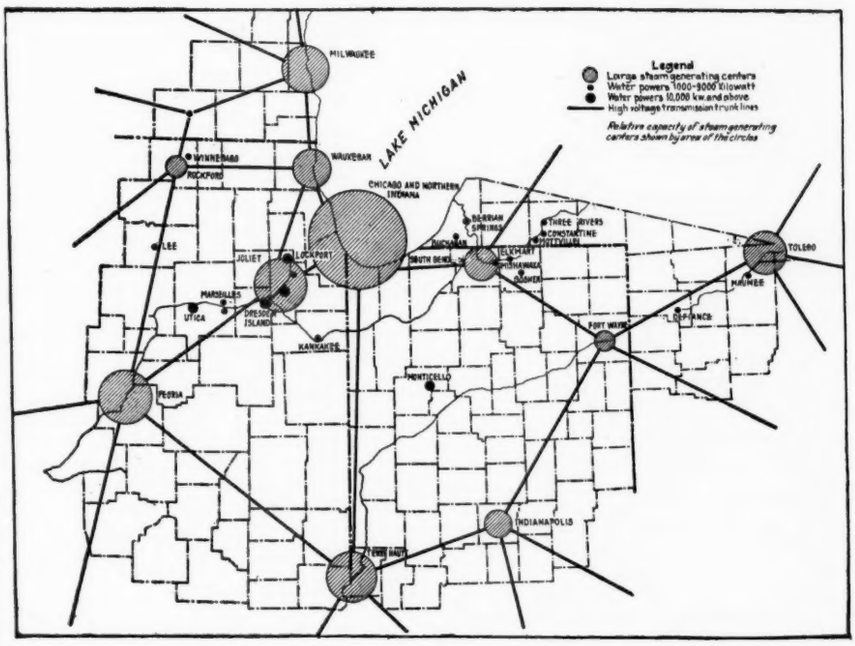
"The installed primary horsepower in the four states of the Great Lakes Division, has increased from 350,000 hp. in 1869 to nearly 5,000,000 hp. in 1919, or an increase from 55 to 307 horsepower per 1,000 of population in 50 years. This compares with the figures for the whole United States showing an increase from about 60 horsepower per 1,000 people in 1869 to 280 horsepower per 1,000 people in 1919, an indication of over 500 horsepower per 1,000 people in 1950. The installed horsepower in Area A in all industries was 2,862,000 hp. in 1920 or 340 hp. per 1,000 of population."

The region designated as Area A is lacking in extensive water-power possibilities. The Great Lakes, however, furnish sufficient water for condensing purposes which, added to the fact that this area is underlaid with coal deposits and two producing oil fields in the territory covered by the survey, would indicate that steam plants will be the basis for future power development.

The Wabash River, below Attica, Ind., is underlaid with coal deposits for a considerable part of the distance to its mouth. It is very likely that a number of large-sized generating stations could be located on this river a few miles apart and generate power at low cost to transmit to other parts of the territory.



Area "A" in 1923—Installed capacity of generating stations



Area "A" in 1950. An arrangement of generating centers and trunk lines to meet estimated energy requirements

Puget Sound Power Merger Links Plants

A. W. Leonard, of the Puget Sound Power & Light Co., has announced the completion of the merger of all subsidiary companies. The concerns losing separate identity are the Washington Coast Utilities Co., the North Coast Power, and the Olympia Light & Power Co. The consolidation, a Stone & Webster corporation, now owns and operates practically all the major utilities in western Washington from the Canadian boundary to the Columbia River and reaches into the Wenatchee Valley in eastern Washington.

Controversy Between Hydro and Fish Settled

Construction work on the hydro-electric plant of the Puget Sound Power & Light Co. at Concrete, on Baker River in Skagit County, Wash., may begin at any time, following the withdrawal of the protest filed by the United States Bureau of Fisheries. The company has proposed two methods whereby the development will not interfere with the fish. It will construct a pond below the dam, and the Bureau is to catch and place a quantity of adult salmon taken while en route to Baker Lake and determine whether they can be held to maturity below the dam. Should this method fail, the company will install and operate a lift that will put the live fish into a pond above the dam and will permit an overflow over or through the dam during the month of June each year to permit the young salmon to migrate down stream.

The proposal of the company has met the approval of the Bureau and removes the only obstacle to the site. The plant will have a capacity of 45,000 hp. and will cost about $500,000.

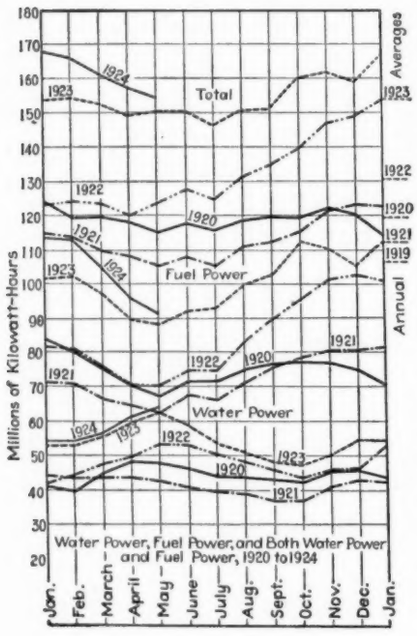
Civil Engineers Differ on Boulder Dam

A lively discussion took place at the recent San Francisco convention of the American Society of Civil Engineers over a paper by Col. William Kelly, chief engineer of the Federal Power Commission, on "The Colorado River Problem." A. P. Davis, J. C. Allison, F. H. Fowler, Louis C. Hill, E. C. LaRue, Major H. S. Bennion and William Mulholland presented views from different angles on power and irrigations needs in the Colorado River basin, some opposing and some defending the Boulder Cañon dam.

The Mojave reservoir was advocated as a means of solving several of the more troublesome problems and was also vigorously decried as the revival of a scheme undesirable and ill-advised which was long ago abandoned as impracticable. Speakers mentioned the great importance of an agreement with Mexico before any extensive storage work was undertaken.

Production of Electricity Decreases

The average daily production of electricity by public-utility power plants in May was 154,700,000 kw.-hr., about 2 per cent less than the daily output for the month of April. The curve of average daily total output for 1924, shown below, indicates that the



Power curve descends

production of electricity by public-utility power plants for the first five months of this year has been affected by about the normal seasonal decline in the demand for electricity which occurs every year during the spring and summer months. The curve showing the output by the use of water power shows the usual gradual increase in output due to the increase in the flow of streams, which generally reaches the maximum in May or June.

The average daily production of electricity by public-utility power plants and the proportion produced by water power for each month of this year were as follows: January, 167,400 kw.-hr., 32.3 per cent; February, 166,700,000 kw.-hr., 32.3 per cent; March, 160,800,000 kw.-hr., 34.4 per cent; April, 158,000,000 kw.-hr., 39.0 per cent; May, 154,700,000 kw.-hr., 40.6 per cent.

The Patent Office Needs Assistant Examiners

The Civil Service Commission has announced an examination to be held on Aug. 20 and 21 for positions of assistant examiner in the United States Patent Office at Washington.

The entrance salary is $1,860 a year. Promotions are provided for from time to time which bring salaries up as high as $5,000 a year. One hundred additional places are provided by the recent appropriation act. There is therefore exceptional opportunity for appointment of those who pass the examination.

The examination consists of physics, interpretation of mechanical drawings, technics, mathematics, modern languages, and some branch of engineering.

S.P.E.E. Holds Important Meeting

The Society for the Promotion of Engineering Education held its 32d annual meeting at the University of Colorado, Boulder, Colo., June 25-28. The attendance was 362, exceeding all former records. The 150 members present represented 70 colleges, 38 states, Canada and Hawaii. The large registration was in part due to the attractiveness of Colorado for summer vacation programs.

The entertainment features of the meeting included a mountain canyon drive, inspection of an 1,800-ft. head hydro power plant and a steam power plant which will ultimately cost $12,000,000.

The dominating characteristic of the sessions was the comparative absence of lengthy expressions of personal opinion and the substitution therefor of the presentation of educational research data and ideas. Dean G. B. Pegram of Columbia University explained the present situation of the six-year engineering courses at his institution, which is, that, although the work is satisfactory, very few students are graduating from the courses.

On Thursday Professor W. H. Burgess, of Northwestern University, read a paper by himself, and director J. F. Hayford, "Fifteen Years of Experience with a Five-Year Engineering Curriculum." Northwestern likes the arrangement, and the attendance, though small, has averaged 9 per cent annual increase. But only 13 per cent of the students who enter complete the fourth year and 8 per cent the fifth year, as compared with 35 per cent to 40 per cent in the average four-year engineering courses.

Iowa State College reported that more than 25 per cent of her engineering graduates have had college work preliminary to entering an engineering course, to such an extent that they have completed five to eight years' total college work upon graduation, which is as large a percentage of those entering as the total graduates at Northwestern.

Many engineering educators believe that five- or six-year engineering courses are needed for the adequate training of present-day engineers, but most of them also believe that such courses cannot be made successful without concerted action by all the best engineering colleges and by the engineering profession as a whole. Director Wickenden, of the Board of Investigation and Co-ordination, strongly supported this view the next day, and on Saturday he urged that preparation for concerted action by the engineering colleges on this and other matters be made by an effective organization of the institutional delegates.

Mr. Wickenden is chairman of the board that is administering the $108,000 fund created by the Carnegie Foundation for the study of engineering education to be carried out under the direction of the society. The grant was made in late October of last year, Mr. Wickenden was appointed director in November and the Board of Investigation and Co-ordination was set up by the society in March of this year. The board contains ten members representing all branches of the profession.

The present attitude of engineering educators on the proper length of engineering curricula seems to be one of watchful waiting. The belief is growing that mere juggling with the details of the present four-year courses can effect only minor improvements and that any great advance in engineering education will require longer curricula.

Very comprehensive plans for the great research upon which the engineering colleges are entering were reported. The co-operation has been secured of the great industrial organizations (through the Joint Industrial Conference Board) and of the great national engineering societies (through a joint council). These agencies will assist in making job analyses of the work of engineers in different occupations and of the numbers of engineering graduates required to meet the needs of the country. It is an organization comprehensive enough, to conduct a thorough research to ascertain the true fundamental data of engineering education, and, by concerted action to put into effect whatever improvements may be found advisable.

The new officers of the society are: President, Dean A. A. Potter of Purdue; vice-presidents, Prof. R. S. King, Georgia Institute of Technology, and Dean G. B. Pegram, Columbia University. Members of the council for three years, Dean G. M. Butler, University of Arizona; Prof. H. Pender, University of Pennsylvania; Dean E. B. Norris, State College of Montana; Prof. W. E. Brooke, University of Minnesota; Assistant Dean H. H. Jordan, University of Illinois; Prof. W. H. Kenerson, Brown University, and Director W. E. Wickenden. The secretary, Dean F. L. Bishop, of Pittsburgh, and the treasurer, W. O. Wiley, of New York, were re-elected.

Engineering Museum Wants Ten Million Dollars

The National Museum of Engineering and Industry, Inc., with headquarters in the Engineering Societies Building, 29 West 39th St., New York City, which was incorporated in the District of Columbia last March is making a drive for $10,000,000, one million of which has been assured. A campaign to raise the additional $9,000,000 was started on July 5.

The president of the new organization is Dr. Elihu Thompson, who on July 10 received the Kelvin gold medal from the Royal Society at the Kelvin centenary in London. The vice-presidents are: Dr. Edward G. Acheson, one of the creators of the modern abrasive industry; Dr. Leo H. Baekeland, president of the American Chemical Society, and Dr. Edward Weston, creator of the Weston type of electrical instruments. Its trustees are Philip T. Dodge, chairman of the International Paper Co., Howard Elliott, chairman of the Northern Pacific R.R., Dr. Ira N. Hollis, president of the Worcester Polytechnic Institute, Dr. Elmer A. Sperry, president of the Sperry Gyroscope Co., and Worcester R. Warner, of Warner & Swasey, Cleveland, Ohio. George E. Roberts, vice-president of the National City Bank, is treasurer, and H. F. J. Porter is secretary.

Deschutes River Projects Get License

The Federal Power Commission has authorized the issuance of a license to the Columbia Valley Power Co. covering two proposed developments in the Deschutes River in central Oregon. Various conditions, however, are attached to the license. A preliminary permit covering the two sites was issued to this company on Feb. 6, 1923.

The license covers the construction at the Pelton site of a masonry dam 165 ft. high at which 51,000 hp. will be developed. The company furnished satisfactory plans for the proposed structure. At the Metolius site, the other one involved, which is eight miles above Pelton, it is proposed to construct a dam 330 ft. high. The detailed plans for this development have not been worked out, but the applicant proposes to prepare them during the construction of the Pelton development.

The Columbia Valley company sets forth in its application that a portion of the power it will develop probably will be sold to the two public-utility companies operating in Portland. It is stated that within five years these utilities will have to have 40,000 hp. additional. Power can be developed, it is stated, on the Deschutes River cheaper than at sites controlled by the utility companies on the Clackamas River in Oregon and on the Lewis River in Washington. The company also advises the Federal Power Commission that other markets for power have been investigated, and the opinion is expressed that the full output of the Pelton plant can be utilized on its completion and that the construction work will have to go ahead immediately on the Metolius plant.

Turbine Research Engineer Dies Suddenly

Wilfred Campbell, one of the well known turbine engineers of the country and recently famed for his brilliant investigation of the axial vibration of steam-turbine disk wheels, died at Schenectady, N. Y., on July 7, as a result of complications following an operation for appendicitis. Born in Manchester, England, in 1884, Mr. Campbell came to America in 1907 and associated himself with the G. E. Company, where he worked during the recent war, with Dr. Irving Langmuir and C. E. Eveleth, on research and design work on submarine detectors.

Since 1919 Mr. Campbell has been an engineer in the turbine department, and last December received an award

Wilfred Campbell

from the Charles A. Coffin Foundation in recognition of his contribution to turbine research and design. The results of this long and fruitful research were presented before the Society of Mechanical Engineers on May 26 in a paper, "Protection of Steam Turbine Disk Wheels from Axial Vibration," which will remain a monument to his patient and painstaking ability.

In commenting on Mr. Campbell's death, Francis C. Pratt, who was in charge of the engineering department, said:

"Mr. Campbell's sudden death is a great shock to his many friends and associates in the company. When he undertook this important work, in 1919, investigation of turbine wheel vibrations, it was thought by some engineers that the limit in the size of individual turbine units had been reached. Mr. Campbell had a rare genius for analyzing and solving abstruse problems of a mechanical nature and did not share these adverse opinions regarding the limitations in the size of steam turbines. He discovered the cause of the troubles with large turbine wheels and buckets, devised remarkably ingenious methods of detecting and measuring the phenomena connected with them, and provided means for overcoming them. He has made a fine and lasting contribution to the industry, and his work will long be remembered by engineers who design and operate steam turbines."

Mr. Campbell is survived by his widow and four children.

Pinchot Names Giant Power Board

The appointment of the members of the Giant Power Advisory Board, of which Maj. Gen. William Crozier, former chief of the Ordnance Department of the Army, is chairman, was announced at Governor Pinchot's office at Harrisburg, Pa., on July 10. The Board will be asked to pass on the final report of the Giant Power survey before it is submitted to the Pennsylvania Legislature.

The appointees included: Dr. Charles W. Eliot, President Emeritus of Harvard University; William Allen White, of Emporia, Kan.; Fred A. Gaby, of the Hydro-Electric Power Commission of Ontario, Canada; John R. Freeman, of Providence, R. I.; Henry L. Stinson, of New York City; Arthur J. Mason, of Chicago; Raymond B. Stevens, of Landaff, N. H.; William Kent, of Kentfield, Cal.; Professor Henry S. Graves, of the Forestry School of Yale University; Martha Brinsley Bruere, of New York City; Harry A. Garfield, of Williams College; William B. Mayo, of Dearborn, Mich.; James R. Garfield, of Cleveland; William Mulholland, of Los Angeles; Joseph N. Teal, of Portland, Ore., and Mrs. Maud Wood Park, of Washington, D. C.

Personal Mention

Horace P. Liversidge, who has been assistant chief engineer of the Philadelphia Electric Co., was recently elected vice-president of the company.

Jackson & Moreland, consulting engineers, have moved from 387 Washington St. to the Park Square Building, 31 St. James Ave., Boston, Mass.

H. G. Butler, who has been engaged since 1921 in private practice as consulting engineer, has been made power supervisor under the California State Railroad Commission.

E. M. Ashworth who has been serving the Toronto Hydro-Electric System as acting general manager for some time, during the absence of H. H. Couzens, has recently been appointed general manager.

R. M. Fullerton has been appointed superintendent of shops for the B. F. Sturtevant Co., Hyde Park, Mass. Mr. Fullerton was formerly electrical engineer of the company, with headquarters at the Hyde Park factory.

Walter H. Johnson, who has just retired as president of the N.E.L.A., has been elected president of the Philadelphia Electric Co. Mr. Johnson was formerly chief assistant to Joseph B. McCall, former president, who resigned to become chairman of the Board of Directors.

William A. Durgin, who for two and a half years has been at the head of the Division of Simplified Practice of the

Department of Commerce, has left his government activity to resume his former post with the Commonwealth Edison Co. of Chicago, from which he was borrowed by Secretary Hoover when the latter established the Division of Simplified Practice.

Business Notes

The Brown Instrument Co., Philadelphia, Pa., manufacturer of indicating and recording instruments, announces the appointment of R. D. Dean as chief engineer.

The Industrial Works, Bay City, Mich., announce the appointment of Ridenour, Seaver & Kendig, 773 Ellicott Square, Buffalo, N. Y., as their representatives in the Buffalo district, with L. N. Ridenour as resident manager.

M. H. Detrick Co., Chicago, Ill., has consolidated the general offices and the engineering service department of the company with the Chicago sales office, and the entire organization now has commodious quarters at 140 South Dearborn St.

The Maine Electric Co., Portland, Maine, manufacturer and distributor of steam and electric hoists and derricks, coal-handling plants and marine auxiliary machinery, has opened a Philadelphia office at 814 Walnut St., with F. V. Wetherill in charge.

The Chain Belt Co., Milwaukee, Wis., at its recent annual meeting elected the following officers: J. C. Merwin, former works manager, was elected second vice-president; Brinton Welser was made secretary and C. E. Stone, assistant secretary. In addition, the following officers were re-elected: C. R. Messinger, president; Clifford F. Messinger, first vice-president and C. L. Pfeifer, treasurer.

The J. G. White Engineering Corp., of New York City, has been commissioned by the Staten Island Edison Corp. to design and build an addition to the Livingston power plant, including installation of a 15,000-kw. unit with necessary auxiliaries; also to design and construct substations at Livingston, Eltingville, Atlantic, Arrochar, Clifton Junction, Dongan Hills and St. George, with transmission line from Livingston to Clifton Junction and thence to Eltingville and Arrochar.

The Ridgway Dynamo & Engine Co., 7016 Euclid Ave., Cleveland, Ohio, announces that Peter G. Rimmer, for many years in charage of the Wilkes Barre office of the Ridgway company has resigned the position which he has held for the last two years with the Scranton Electric Construction Co. and will again be in charge of the Ridgway office at Wilkes Barre. E. W. Quiggle, who has been in charge of this office during Mr. Rimmer's absence, will return to the factory at Ridgway, Pa.

The Indiana Pump Company, Indianapolis, Ind., manufacturer of air-lift equipment, and the Chicago Pneumatic Tool Co., New York City, builders of air compressors, announce the establishment of an agreement whereby each organization will use jointly and exclusively the products of each other on all their air-lift installations. Technical consultation relative to the combined unit is available at any one of the many branches of either company.

The De Laval Steam Turbine Co., Trenton, N. J., announces the formation of a Pacific Coast sales organization under the direction of William Pullen, with offices in Los Angeles, San Francisco and Seattle. The Los Angeles office is in the Union Oil Bldg., 617 West Seventh St., and is in charge of Ivan E. Goodner. The San Francisco office is in the Rialto Bldg., Mission and New Montgomery Sts., with Mr. Pullen in charge, assisted by Eck Baughn and Charles P. Markley. The Seattle office is in the L. C. Smith Bldg., and James Q. Osborne is in charge, assisted by F. A. Hurlburt.

Coming Conventions

American Ceramic Society. Ross C. Purdy, Lord Hall, Ohio State University, Columbia, Ohio. Summer meeting and tour. July 21 to Aug. 13.

American Chemical Society. Dr. Charles L. Parsons, 1709 G St., N. W., Washington, D. Q. Sixty-eighth meeting at Cornell University, Ithaca, N. Y. Sept. 8-13.

American Electric Railway Association. James W. Welsh, 8 West 40th St., New York City. Meeting at Atlantic City, Oct. 6-10.

American Electrochemical Society. Dr. Colvin G. Fink, Columbia University, New York City. General meeting at Detroit, Mich., Oct. 2-4.

American Institute of Chemical Engineers. Dr. John C. Olsen, Polytechnic Institute of Brooklyn, New York. Summer meeting in Denver, July 15-18.

American Institute of Electrical Engineers. F. L. Hutchinson, 29 West 39th St., New York City. Fall convention at Pasadena, Calif., Oct. 13-17.

American Institute of Mining and Metallurgical Engineers. F. F. Sharpless, 29 West 39th St., New York City. Autumn meeting at Birmingham, Ala., Oct. 13-15.

American Society of Civil Engineers. John H. Dunlap, 29 West 39th St., New York City. Fall meeting at Detroit Oct. 23-25.

American Society of Mechanical Engineers. Calvin W. Rice, 29 West 39th St., New York City. Annual meeting at New York City, Dec. 1-4.

American Society of Refrigerating Engineers. W. H. Ross, 35 Warren St., New York City. Annual meeting at New York City, Dec. 1-3.

Association of Iron & Steel Electrical Engineers, John F. Kelly, 1007 Empire Bldg., Pittsburgh, Pa. Annual meeting and exposition at Duquesne Garden, Pittsburgh, Pa., Sept. 15-20.

Illuminating Engineering Society. Norman D. MacDonald, 29 West 39th St., New York City. Convention at Briarcliff Lodge, Briarcliff Manor, N. Y., Oct. 27-31.

International Union of Steam and Operating Engineers. Dave Evans, 6334 Yale Ave., Chicago, Ill. Biennial convention at Detroit, Mich., Sept. 8-13.

Management Congress, First International. Prague, Czechoslovak, July 21-24.

National Association of Practical Refrigerating Engineers. E. H. Fox, 5707 West Lake St., Chicago, Ill. Convention at New Orleans, La., Nov. 11-14. Exhibits at the Isaac Delgado High School.

National Association of Stationary Engineers. Fred W. Raven, 417 South Dearborn St., Chicago, Ill. Annual convention and exhibition at Hotel Pantlind, Grand Rapids, Mich., Sept. 8-13. Annual conventions and exhibitions of the state associations are scheduled as follows: **New England States Association** at Cambridge, Mass., July 24-26, formerly announced July 10-12. Freeman L. Tyler, 32 Briggs St., Taunton, Mass. **Wisconsin Association** at Fond du Lac, July 24-26. Vincent Todd, 25 Fourteenth St., Fond du Lac. **Minnesota Association** at Faribault, Minn., July 31, Aug. 1-2. C. A. Nelson, 800 22nd Ave., N. E. Minneapolis. **Michigan Association** at Grand Rapids, Sept. 8. Wm. H. Yeomans, 209 Plainfield Ave., Grand Rapids. **Pennsylvania State Association** at Grand Rapids, Mich., Sept. 8. J. N. Calvert, Union & Ridenour Ave., Crafton, Pittsburgh, Pa.

New England Water-Works Association, Frank T. Gifford, 715 Tremont Temple, Boston, Mass. Annual convention at Powers Hotel, Buffalo, N. Y., Sept. 23-26.

Trade Catalogs

Boilers — Heine Boiler Co., Saint Louis, Mo. Leaflet, "In the Footsteps of Old Masters," tells of the early boilers installed by this company.

Tanks, Surge—Larner Engineering Co., Philadelphia, Pa., has published an attractively illustrated bulletin describing the Johnson "Differential" Surge Tank.

Refrigerating Machinery—Milwaukee Steam Appliance Co., West Allis, Wis., Leaflet describing refrigerating machinery from ½ to 10 ton capacities manufactured by this company.

Pumps—Chicago Pneumatic Tool Co., 6 East 44th St., New York City. Bulletin No. 711 "Crescent 'Roto-Piston' Dry Vacuum Pumps," is a well-illustrated description of this equipment.

Indicating Instruments—The Foxboro Co., Inc., Foxboro, Mass. Bulletin No. 96-1 describes briefly yet completely the many different types of indicating recording and controlling instruments made under the Foxboro trade-mark.

Loaders—The Link Belt Co., Philadelphia, Pa. Book No. 650 is a well-illustrated catalog covering the different loaders manufactured by this company. Specifications and explanatory drawings are included.

Valves—J. H. H. Voss, Inc., 154 Nassau St., New York City. *Voss Valve News* describes ammonia compressor valve design II. Illustrations and drawings of valves manufactured by this company are included.

Instruments, A.-C. Portable—Roller-Smith Co., 233 Broadway, New York City, Bulletin No. 160, just off the press, describes in detail the new Type GSA alternating-current portable instruments manufactured by this company.

Cranes—Link Belt Co., Philadelphia, Pa. Book No. 670 describes the locomotive and crawler cranes built by the company which are adapted for the handling of coal, materials and commodities as well as for use in excavations.

Turbo-Generator Sets—The Ridgway Dynamo & Engine Co., Ridgway, Pa., Bulletin No. 31 is a 26-page booklet describing with illustrations the turbo-generator sets manufactured by this company.

Refractories—Keystone Refractories Co., 120 Liberty St., New York City. Booklet describing the application and properties of "Key-Cel-Brix" the calcined insulating brick manufactured by them.

Superheaters—The Superheaters Co., of New York and Chicago, manufacturer of Elesco superheaters, has just published a booklet, "Origin, Development and Results of Elesco." It gives in brief form the history of the Superheater Co. and the growth of its operations up to the present time. The development of the use of high-degree superheated steam is traced from the earliest experiments of the late Dr. Wilhel Schmidt, of Cassel, Germany, to the present tendencies in steam generation in this country.

Packing—The Garlock Packing Co., Palmyra, N. Y. Catalog "Quality Controlled Packings have the Same Service Stamina Today and Tomorrow as They Had Yesterday," contains pictures illustrating the fact stated in the title.

Valves—The Merco Nordstrom Valve Co., a subsidiary of the Merrill Co., of San Francisco, has just issued a new loose-leaf catalog combining a series of bulletins, to which others may be added, describing with illustrations the Merco Nordstrom Plug Valve.

Pumping Systems, Air Lift—The Sullivan Machinery Co., 122 South Michigan Ave., Chicago, Ill. Bulletin No. 71-H explains with illustrations the important advantages of air-lift pumping when properly applied and shows how the equipment of this company secures a high degree of effectiveness in this field.

Fuel Prices

BITUMINOUS COAL

The following table shows the trend of the spot steam market in various coals (mine run bases, f.o.b. mines):

Coal	Market Quoting	June 30, 1924	July 7, 1924
Pool 1	New York	$2.70	$2.90
Smokeless	Columbus	2.20	2.35
Clearfield	Boston	1.95	2.20
Somerset	Boston	2.15	2.50
Kanawha	Columbus	....	....
Hocking	Columbus	1.70	1.85
Pittsburgh No. 8	Cleveland	1.85	1.95
Franklin, Ill.	Chicago	2.35	2.50
Central, Ill.	Chicago	2.10	2.25
Ind. 4th Vein	Chicago	2.35	2.50
West Ky.	Louisville	1.60	1.75
S. E. Ky.	Louisville	1.55	1.75
Big Seam	Birmingham	2.10	2.10

FUEL OIL

New York—July 10, light oil, tank-car lots, 28@34 deg. Baumé, 5½c. per gal., 36@40 deg. 6c. per gal., f.o.b. Bayonne, N. J.

St. Louis—July 1, tank-car lots, f.o.b. St. Louis; 24@26 deg., $1.55 per bbl.; 26@28 deg., $1.60 per bbl.; 28@30 deg., $1.65 per bbl.; 30@32 deg., $1.70; 32@36 deg., gas oil, 4.7c. per gal.; 38@40 deg. 5.5c. per gal.

Pittsburgh—July 9, f.o.b. local refinery, 30@40 deg., fuel oil, 5½c. per gal.; 36@40 deg., fuel oil, 5⅝c. per gal.; 34 deg., neutral, 8½c. per gal.

Dallas—July 5, f.o.b. local refinery, 26@30 deg., $1.30@$1.35 per bbl.

Philadelphia—July 3, 28@30 deg., $2.10@$2.163 per bbl.; 18@22 deg., $2.10@$2.16½; 13@16 deg., $1.78½@$1.848 per bbl.

Boston—July 5, tank-car lots, f.o.b. heavy oil, 12@14 deg. Baumé, 4¾c. per gal., light oil, 28@32 deg. Baumé, 6¾c. per gal.

Cincinnati—July 1, tank-car lots, f.o.b. local refinery, 24@26 deg., Baumé, 4¾c. per gal.; 26@30 deg., 5½c. per gal.; 30@32 deg., 5⅝c. per gal.

New Plant Construction

Ala., Andalusia — The Andalusia Mfg. Co. plans for a boiler house at its mill, for which plans are being perfected. E. R. Merrill, head.

Ala., Birmingham—The Alabama Water Co., American Trust Bldg., is planning for a bond issue of 300,000, a portion to be used for extensions and improvements in plants and systems at Anniston, Bessemer, Greensboro, and other points, including electric pumping machinery and accessory equipment.

Ala., Selma — The City Council contemplates electric pumping equipment in connection with extensions and improvements in the municipal waterworks, for which it is expected to issue bonds for $150,000.

Calif., El Monte—The Pasadena Ice Co., Pasadena, Calif., is considering a new ice-manufacturing plant on Hoyt St., to cost $45,000, with equipment. The local Chamber of Commerce is interested in the project.

Calif, Guadalupe—The Golden State Milk Products Co. contemplates an ice and refrigerating plant at its proposed creamery. The entire works will cost $65,000.

Calif., Reedley — The Board of City Trustees plans for centrifugal pumping equipment for its proposed sewerage system, to cost $130,000. Bonds will soon be voted.

Calif., Ukiah — The Board of City Trustees has authorized the purchase of pumping equipment at the municipal waterworks.

Calif., Upland—The West Ontario Citrus Association will break ground at once for a new packing house, to include an ice and precooling plant. The project to cost about $85,000.

Colo., Denver — The Midwest Refining Co. plans for a number of pumping plants and booster stations for its proposed pipe line from its oilfields in Northern New Mexico, about 22 miles.

D. C., Bellevue—The navy supply officer, Navy Yard, has been authorized to purchase one American rotary vacuum pump, as per specifications on file.

Fla., Anna Maria—The Town Council is planning for a municipal electric plant. An ice-manufacturing plant will also be installed. W. B. Kirby, Bradentown, Fla., engineer.

Fla., Homestead—The City Council has arranged a special election on July 22 to approve bonds for $235,000 for extensions and betterments in the municipal water plant and sewerage system, to include electric pumping equipment. Charles W. Murray, Miami, Fla., engineer.

Fla., Largo — The Common Council is planning for electric pumping equipment in connection with extensions in the municipal waterworks.

Ga., Atlanta—The American Box & File Co. contemplates a boiler plant at its mill, for which plans are being drawn by E. C. Seiz, 43½ Peachtree St., architect. The works will cost $65,000.

Ga., Atlanta—The United Cleaners, Inc., P. O. Box 1652, is planning for the purchase of a 150 kva. engine-generator set.

Ga., Pelham — The Common Council contemplates centrifugal pumping equipment in connection with extensions and improvements in the municipal waterworks. Bonds will be voted early in August.

Idaho, Troy — The Troy Lumber Co., Eighth and G Sts., plans for the rebuilding of the portion of its mill and boiler plant recently burned. An official estimate of loss has not been announced.

Ind., Hammond—The Northern Indiana Gas & Electric Co. has arranged for a note issue of $4,500,000, a portion to be used for extensions and improvements in power plants and system.

Ind., Hartford City — The Fort Wayne Corrugated Paper Co., Fort Wayne, Ind., plans for a boiler house at its proposed plant, to cost $250,000.

Iowa, Schleswig—Bids will be received by the Town Council until July 21, for pumping machinery and accessory equipment for waterworks improvements, as per specifications on file. Lafayette Higgins & Son, Securities Bldg., Des Moines, Iowa, engineers. Otto A. Hollander, town clerk.

Kan., Pittsburg—The State Board of Administration, Topeka, has plans nearing completion for an addition to the power house at the state teachers' college. Chester M. Rutledge, State House, Topeka, architect.

Ky., Ashland—The City Council is considering a bond issue of $300,000, for extensions and improvements in the municipal waterworks. It is proposed to install electric pumping equipment.

La., Shreveport — George J. Schmitz, 2805 Tracy Ave., and associates, are planning for a cold storage plant. Details will be perfected soon.

Md., Baltimore—The Board of Estimate, City Hall, has approved plans for enlargements in the high pressure pumping station of the fire department to include the proposed municipal steam power station for heating service estimated to cost $160,000. Oil burning equipment will be installed. Plans for an individual steam power station at a cost of $270,000, previously authorized, have been abandoned.

Md., Baltimore — The Mount St. Agnes College, Mount Washington Station, has awarded a general contract to Frainie Brothers & Haigley, 19 West Franklin St., for power house and mechanical laundry, to cost $75,000. A list of equipment will soon be arranged. Frank J. Baldwin, 328 North Charles St., architect.

Md., Manchester—The Glen Rock Electric Light & Power Co. has secured a franchise and plans for the installation of equipment at the municipal lighting station, which will be taken over.

Md., Waldorf—The Southern Maryland Fertilizer Works, Inc., recently organized with a capital of $550,000, is planning for a boiler plant at its works. Albert J. Boyle, Garden Apartments, Baltimore, is one of the heads of the company.

Md., Westminster—The Zile-Neuman Co., 207 East Main St., has tentative plans for a new ice-manufacturing plant on East Main St. An architect will be selected soon. Edward W. Neuman, president.

Mass., Chelsea—Plans are being completed for a power house addition at the

plant of the Forbes Lithograph Mfg. Co., to be used as an engine room. Monks & Johnson, 99 Chauncy St., Boston, architects and engineers.

Mass., Springfield—The Department of Streets and Engineering has awarded a general contract to B. W. Mellon, 293 Bridge St., for a boiler plant, at the Taylor St. yard, for municipal service. McClintock & Craig, 33 Lyman St., architects.

Mich, Detroit—The Detroit Free Press plans for a boiler plant and pumping station in its new printing plant and office building on West Lafayette St., near Cass St., estimated to cost $2,715,000. Albert Kahn, Marquette Bldg., architect.

Mich., Jackson—The Consumers' Power Co. is perfecting plans for its proposed hydro-electric plant on the Manistee River, near the county line, with initial output of 21,300 hp.

Mich., Saginaw—The Dittmar & Raths Oil Co., Flint, Mich., Otto E. Dittmar, president, plans for a pumping plant at its proposed oil storage and distributing plant on Durant St. J. Fred Brockbiseinger, 114 South Jefferson Ave., Saginaw, architect.

Mo., Caruthersville—The Arkansas-Missouri Power Co. is planning for a bond issue of $664,000, a portion to be used for the purchase of existing power plants and ice-manufacturing plants, and for proposed expansion, including equipment.

Md., Ridgeley — The Common Council contemplates centrifugal pumping equipment for the proposed extensions and improvements in the municipal waterworks and sewerage plant. It is expected to vote bonds in August.

Mo., St. Louis—L. Boehm, 615 Chamber of Commerce Bldg., is in the market for a 1000 kw. turbo-generator, 3-phase, 60-cycle, 2300-volt, with accessory equipment.

Mont., Missoula—The Utah-Idaho Sugar Co., Salt Lake City, Utah, plans for a steam power plant at its proposed local beet sugar mill; the entire works will cost $300,000.

Neb., Fairbury—The City Council will soon erect an addition to the municipal power plant, to include boilers and auxiliary equipment. Henry W. Fouts, city clerk.

Neb., Otoe — The Common Council is planning for a municipal waterworks, to include electric pumping equipment.

N. Y., Binghamton—Bids are being asked on a general contract by the Board of Contract and Supply, City Hall, for a power house and hospital addition at the city hospital, to cost $650,000. Walter Whitlock, Security Bldg., architect; A. R. Acheson, Eckel Theater Bldg., Syracuse, N. Y., steam and electric engineer. A list of equipment will soon be arranged.

N. Y., Brooklyn—Steam power equipment, ovens, etc., will be installed in the addition to the baking plant of the Drake Brothers Co., Clinton and Park Aves., to cost $87,000. Dodge & Morrison, 160 Pearl St., New York, architects.

N. Y., Elmhurst—The American Ice Co., City Center Bldg., Philadelphia, Pa., has acquired the Elmhurst Ice Co., with three existing ice-manufacturing plants at Elmhurst, Astoria and Glendale, L. I., and is planning for extensions and improvements, including additional equipment.

N. Y., Long Island City—The Sun Oil Co., Finance Bldg., Philadelphia, Pa., contemplates pumping equipment at its proposed storage and distributing plant at East Ave. and First St., to cost $200,000. J. H. Pew, president.

N. Y., New York—In connection with the proposed purchase of the Riordan Co., Montreal, Que., by the International Paper Co., 100 East Forty-second St., the last noted company is reported to be planning for the development of hydro-electric plant sites of the Riordan organization for a total output of 160,000 hp., to be used for mill service.

N. Y., New York—The Brambach Piano Co., 639 West Forty-ninth St., contemplates a boiler plant at its factory on site purchased on Fifty-first St., near Eleventh Ave., to cost $700,000, with equipment. Russell G. Cory, 30 Church St., architect and engineer.

N. Y., New York—The Navy Purchasing Office, South and Whitehall Sts., has been authorized to purchase eight 2-ton chain hoists, as specified in N. S. A. requisition 1052.

N. Y., Potsdam—The St. Lawrence Valley Power Corp. has taken over and merged the Hannawa Falls Water Power Co., re-incorporating under state laws with capital of $5,750,000. Plans are said to be under way for hydro-electric power development at the power site of the acquired company.

N. Y., Rome—The Rome Gas, Electric Light & Power Co., a subsidiary of the Northern New York Utilities, Inc., Watertown, N. Y., has disposed of a bond issue of $600,000, a portion to be used for extensions and betterments in power plants and system.

N. Y., S. I., Tompkinsville—The Staten Island Edison Corp. has disposed of a bond issue of $1,600,000, a portion to be used for extensions and improvements in power plant, including a 15,000 kw. generating unit and auxiliary equipment. J. H. Pardee, president.

N. Y., Utica—The Utica Gas & Electric Co. has issued bonds for $3,300,000, a portion to be used for extensions in power plant and system. Contract has been let to the Westinghouse Electric & Mfg. Co., for two 15,000 kw. turbo-generators and accessory equipment, and other equipment. Orders will soon be placed.

N. C., Charlotte—The Carolina Standard Gas Products Co., 256 Clifton Ave., Atlanta, Ga., Philip W. Wilcox, president, plans for a boiler house at its proposed plant for the production of commercial oxygen etc. The entire works will cost $150,000.

N. C., Lattimore—The Common Council contemplates a municipal electric plant. Bonds will be voted and plans drawn soon.

N. C., Laurinburg—The Common Council plans for electric pumping equipment in connection with a proposed municipal waterworks. Bonds for $175,000 have been issued.

N. D., Grand Forks—The Common Council has plans under consideration for a municipal electric plant, to cost $120,000, with equipment. It is proposed to install a Diesel engine, 700 kw. generator, and accessory equipment. Charles M. Evanson, city clerk.

Ohio, Cincinnati—The Columbia Power Co. has taken bids for steel frame superstructure for its steam electric generating plant, and purposes to begin work soon. The station will cost $5,000,000, with equipment.

Ohio, Youngstown — The Pennsylvania-Ohio Power & Light Co., an interest of the Pennsylvania-Edison Co., has issued bonds for $19,000,000, a portion to be used for extensions and improvements in plants and system.

Okla., Tipton—Bonds have been voted for $51,000 for a municipal waterworks, to include a pumping plant. Plans will be drawn by V. V. Long & Co., Colcord Bldg., Oklahoma City, Okla., engineers.

Okla., Tulsa—The Tulsa County Commissioners, Water Improvement District No. 1, contemplate a pumping plant in connection with a proposed system, to cost $250,000. A bond election will soon be held. The Benham Engineering Co., Gimbel Bldg., Kansas City, Mo., engineer.

Ore., Arlington — The Common Council is considering electric pumping equipment in connection with improvements and extensions in the municipal waterworks. Stevens & Soon, Spalding Bldg., Portland, engineers.

Ore., Bay City — The Oregon Silver Spruce Co. plans for a boiler plant at its mill, to replace a works recently burned. It is estimated to cost $80,000.

Pa., Chester — The City Council contemplates electric pumping equipment for its sewerage disposal works. The entire plant will cost $2,500,000. Plans have been authorized by the State Health Department.

Pa., Philadelphia — The Board of Trustees, Girard College, Girard and Corinthian Aves., has awarded a general contract to E. H. Keefer & Son, 1321 Rodman St., for an addition to the mechanical school, to cost $375,000. Steam engine equipment and other steam power apparatus will be installed for instruction of students. John T. Windrim, Commonwealth Bldg., architect.

Pa., Philadelphia — Boyer & Crawford, Inc., has filed plans for a boiler plant at their factory at J and Venango Sts.

S. C., Graycourt—The Common Council is perfecting plans for a municipal electric plant. A bond issue will soon be sold.

S. C., Greenville—The Greenville Community Hotel Corp. plans for a boiler plant and pumping station at its proposed hotel, estimated to cost $1,000,000. Work will proceed at once.

S. C., Spartanburg—The Dixie Cake Co. plans for a refrigerating plant at its proposed baking plant on Liberty street. Plans will soon be arranged.

Tenn., Decatur—The Decatur Light Co., recently organized, is reported to be planning for a power plant and system. T. G. Davis and John Scott, both of Decatur, head the company.

Tenn., Knoxville—T. L. Lay & Co., 400 East Jackson St., meat packers, have foundations in progress for an addition to be used in part for a cold storage plant.

Tenn., Maryville—The Tennessee Electric Power Co., Chattanooga, is reported to be planning for enlargements in the power plant of the Maryville Lighting Co., recently acquired, including additional equipment.

Tenn., Sparta—The Sun Pigment Paint Co., recently organized, plans for a boiler plant at its factory. The company is headed by Oliver W. Hill, 520 West Church St., Knoxville, Tenn.

Tenn., Summerville—The Common Council is said to be planning for the rebuilding of the municipal electric light plant, recently burned. Estimate of loss has not been announced.

Tex., Bastrop—The Powell Oil Mill Co. is planning for a boiler plant in connection with the proposed rebuilding of the portion of its mill, recently burned with loss approximating $80,000.

Tex., Beaumont—The Magnolia Gas Co. will install two or more pumping plants and booster stations in its new pipe line from a point in Louisiana to Beaumont, about 200 miles. Fred M. Lege, Jr., president.

Tex., Dallas—The Dallas Packing Co., 4903 Worth St., has plans for an ice and refrigerating plant at its proposed packing house. The entire equipment installation is estimated to cost $32,000. B. P. Smith, president, is in charge of purchases.

Tex., San Juan—The Arkansas Pass Compress Co. plans for a boiler plant for its proposed compressing works, including two or three 125 hp. boilers and accessory equipment. The plant will cost $80,000. J. K. Cain president.

Tex., Timpson—The City Council contemplates centrifugal pumping equipment for its proposed extensions in the municipal waterworks. A bond issue will soon be arranged.

Tex., Waco—The Morris Packing Co., 2426 Morrow Ave., plans for a refrigerating and cold storage plant at its proposed factory at Mary and Second Sts. J. D. Lofton, local manager.

Va., Lynchburg—The Lynchburg Stone Co., Peakland St., plans for electric motors, controls and other electric power equipment at its properties. W. H. Lloyd, secretary.

Va., Norfolk—The Virginia Portland Cement Corp., National Bank of Commerce Bldg., plans for a steam plant at its proposed cement mill. The entire plant will cost $1,000,000, with equipment. The company is a subsidiary of the International Cement Corp., 342 Madison Ave., New York.

Va., Portsmouth—The City Commission, J. P. Jersey, city manager, has plans under consideration for a steam electric plant to be used with two electric pumping stations.

Wash., Aberdeen — The Grays Harbor Light & Power Co. has made application for permission to construct and operate a hydro-electric power plant on the Queets River, Jefferson County, to cost $1,000,000, including power dam, steel tower transmission line, etc.

Wash., Port Angeles — The Common Council is considering centrifugal pumping equipment for proposed extensions and improvements in the municipal waterworks. It is proposed to issue bonds for $625,000.

W. Va., Morgantown — The Common Council contemplates electric pumping equipment for proposed extensions and improvements in the municipal sewerage plant and system. Bonds for $600,000, have been approved. The city engineer is in charge.

Wis., Eau Claire—The Common Council contemplates electric pumping equipment in connection with proposed extensions and improvements in the municipal waterworks. A bond issue of $165,000, is being arranged.